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EVALUATION OF THE RELATIONSHIP BETWEEN ANIMAL TEMPERAMENT AND STRESS RESPONSIVENESS TO *M. LONGISSIMUS LUMBORUM* TENDERNESS IN FEEDLOT CATTLE

A Dissertation

by

DAVID ANDREW KING

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 2005

Major Subject: Animal Science

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ABSTRACT

Evaluation of the Relationship Between Animal Temperament and Stress Responsiveness to *M. Longissimus Lumborum* Tenderness in Feedlot Cattle.

(December 2005)

David Andrew King, B.S., Texas A&M University;

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Temperament effects on meat quality were investigated using three contemporary groups consisting of Bonsmara-sired yearling-fed (n = 31), Angus-sired calf-fed (n = 49), and Angus-sired yearling-fed (n = 48) steers. To evaluate temperament, exit velocity, pen scores, and chute scores were determined before shipment to the feedlot, and exit velocity was measured on arrival to the feedlot and after approximately 70 d on feed. Serum cortisol concentration was determined at each evaluation and before slaughter. At slaughter, pH and temperature were monitored in the *M. longissimus lumborum*. USDA yield and quality grade factors and CIE color space values were determined, and *M. longissimus lumborum* steaks were evaluated for sarcomere length, 72-h calpastatin activity, proximate composition, and Warner-Bratzler shear force (WBS) values 3, 7, 14, and 21 d postmortem. Temperament categories were based on rankings within contemporary groups at each evaluation. Temperament traits were consistent across evaluations, and values decreased ($P < 0.05$) in magnitude over time. Relationships between temperament traits were consistent across contemporary groups. Increasing excitability was associated with higher ($P < 0.05$) serum cortisol concentration. Body weight was slightly lower ($P < 0.05$) in cattle with excitable temperaments at all evaluations. Carcass characteristics, proximate composition, muscle color, and calpastatin activity were unaffected by temperament. Carcasses from cattle with calm temperaments had higher 0.5 h postmortem pH values than those from intermediate and excitable cattle (0.1 and 0.2 units, respectively). The Angus-sired yearling-fed steers classified as Excitable had higher ($P < 0.05$) WBS values than the calmer Angus-sired, yearling-fed steers. This trend was observed in the Bonsmara-sired steers, although the values were not statistically different. No differences attributable to temperament were apparent in the Angus-sired calf-fed steers. Correlations were highest between temperament values and tenderness after 21 d. Yearling-fed cattle classified as Excitable before shipment to the feedlot produced tougher ($P < 0.05$) steaks than those from calmer animals. At evaluations later in production, Calm steers produced tougher ($P < 0.05$) steaks. Tenderness did not differ across temperament categories in calf-fed steers regardless of sorting time. These data indicate temperament influences tenderness, though the mechanism is not clear.

DEDICATION

To my parents, Don and Wanda King

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CHAPTER I

INTRODUCTION

Muscle tenderness is a primary factor determining customer satisfaction of beef products. Consumers can discriminate between tenderness differences and are willing to pay premiums for beef known to be tender (Boleman et al., 1997; Shackelford, Wheeler, Meade, Reagan, Byrnes, & Koohmaraie, 2001). Despite significant advancements in the knowledge of factors affecting beef tenderness, the incidence of tough beef continues to be a problem for the beef industry (Brooks et al., 2000). The identification of factors that predispose beef cattle to producing tough meat would aid in designing breeding and management programs to mitigate these factors.

The activation of the hypothalamic-pituitary-adrenal (HPA) axis in response to external stimuli is an important survival mechanism that allows living organisms to maintain homeostasis. The activation of the HPA axis alters the metabolism of various tissues. Prolonged stress responses are associated with reduced growth performance (Mitlöhner et al., 2001: Mitlöhner, Galyean, & McGlone, 2002) and immune response (Minton, 1994). Severe antemortem stressors have been shown to alter postmortem muscle pH decline, resulting in meat quality defects (Apple et al., 1995).

Differences in neurological responses to external stimuli has been related to the stress response and, ultimately, immune capacity (Rosenkranz et al., 2003). Also, previous research has indicated that cattle with more excitable temperaments had more extensive responses to a simulated stress challenge and higher basal levels of

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This dissertation follows the style of *Meat Science.*

glucocorticoids (Curley, 2004). This suggests that stress response mechanisms are much more active in excitable animals than in their calmer counterparts.

Excitable cattle have been reported to have increased incidence of dark cutting lean and increased Warner-Bratzler shear force values than their calmer pen mates (Voisinet, Grandin, O'Connor, Tatum, & Deesing,1997a; Falkenberg, Miller, Holloway, Rouquette, Randel, & Carstens, 2005). Additionally, a low-to-moderate relationship has been observed between exit velocity, pen scores, and chute scores to Warner-Bratzler shear force (Vann, Paschal, & Randel, 2004). The present study was conducted to further investigate the relationships between animal temperament, stress responsiveness, and meat quality of feedlot steers.

CHAPTER II

LITERATURE REVIEW

The activation of the hypothalamic-pituitary-adrenal (HPA) axis in response to stimuli is an important survival mechanism that allows living organisms to maintain homeostasis. Activation of the HPA axis alters carbohydrate, protein, and lipid metabolism to provide energy to address the stimuli. This is the basis for the "fight or flight" response observed when animals encounter a stressor. Negative aspects of this response are reduced growth performance (Mitlöhner et al., 2001, 2002) and immune response (Minton, 1994). Furthermore, antemortem stressors have been linked to meat quality defects such as the dark, firm and dry (Apple et al., 1995) and pale, soft, and exudative (Rosenvold & Anderson, 2003) lean conditions. These defects are attributed to abnormal muscle pH decline caused by stress-induced abnormal glycolytic metabolism. However, it is possible that repeated activation of the HPA axis during growth would have negative consequences on meat quality independent of pH.

2.1. Activation of the hypothalmic-pituitary-adrenal axis

To survive, an organism must maintain homeostasis at the cellular level. When cellular conditions are altered by an exterior factor, the organism attempts to restore homeostasis via a number of mechanisms (Selye, 1936). A factor causing such a response is known as a stressor. Stress responses can be positive (eustress) or negative (distress) experiences. When an animal perceives a stressor, the HPA axis is activated (Harris, 1948; Selye, 1973). Initially, the hypothalamus releases corticotrophin releasing hormone (CRH) and vasopressin (VP; Vale, Spiess, Rivier, & Rivier, 1981; Martini & Morpuso, 1955; Liu et al., 1983). These hormones stimulate the release of adrenocorticotropic hormone (ACTH) by the pituitary gland. In turn, ACTH acts on the adrenal cortex and adrenal medulla to release glucocorticoids and catecholamines, respectively (Hechter, 1949).

Glucocorticoids are a class of hormones derived from cholesterol. Cortisol, the glucocorticoid of primary concern, functions to stimulate gluconeogenesis, proteolysis of muscle tissues, and lipolysis of adipose tissues (Sherwood, 1997). These metabolic shifts serve to ensure the body has adequate energy available to address the perceived stressor. Catecholamines are a class of hormones derived from tyrosine (Sherwood, 1997). Epinephrine is the catecholamine of the greatest significance during a stress response, and has stimulatory effects on α- and β-receptors. When the animal is under stress, catecholamines increase heart rate, raise blood pressure, and increase free fatty acid levels (Shaw & Tume, 1992). Epinephrine also stimulates glycogenolysis and lipolysis and increases overall metabolic rate (Shaw & Tume, 1992; Sherwood, 1997).

The profound effects of the activation of the HPA axis on animal performance and its potential effects on carcass and meat quality have led to extensive research on its constituents. The effects of treatments on the stress status of an animal can be assessed via behavioral responses or measurements of tissues and fluids (Shaw & Tume, 1992). In their review, Shaw and Tume (1992) evaluated both catecholamine and cortisol levels as indicators of stress status. They concluded cortisol concentration was an acceptable gauge of stress response. However, they also noted that a high level of cortisol did not necessarily mean that the stress level was unacceptable.

The HPA axis is activated in response to common management practices. Shaw and Tume (1992) demonstrated increases in glucocorticoids in response to handling and transport. Arthington, Eicher, Kunkle, and Martin (2003) studied the response of freshly-weaned calves to transportation and commingling stressors. Transport increased plasma acute phase protein content and increased shrink during the first day following weaning. In contrast, cortisol levels, which were elevated at weaning, were not affected by transport or commingling. Parker, Hamlin, Coleman, and Fitzpatrick (2003) examined the acid-base balance of steers subjected to feed and water deprivation for 60 h with, and without, transport. Blood pH was not affected by feed and water deprivation or transport. However, partial pressure of CO_2, weak acids, and total proteins in the blood were increased by these treatments. These findings suggest a mild metabolic acidosis occurs during long periods of transport. This is consistent with the effects of transport on the physiological condition of beef cattle (Schaefer, Jones, Tong, & Vincent, 1988; Schaefer, Jones, & Stanley, 1997).

Stress response has long been understood to negatively affect growth and productive efficiency in livestock, and increased stress response has been linked to reduced immune capacity. A common stressor to food animals is heat stress. Mitlöhner et al. (2001, 2002) examined the effect of providing shade and misters in mitigating heat stress in feedlot cattle fed in west Texas during the summer. Those investigators reported that providing shade reduced respiration rates observed during feeding. Additionally cattle provided with shade had higher average daily gains (1.60 versus 1.41 kg/d, respectively), greater dry matter intake and improved feed efficiency than those that did not receive shading. At slaughter, the cattle from shaded pens had heavier carcass weights, greater adjusted fat thicknesses, and higher marbling scores, and a greater percentage carcasses grading USDA Choice, primarily due to a decreased incidence of dark cutting beef.

These results suggest that efforts to reduce exposure to stressors can significantly improve cattle performance and carcass quality.

2.2. Stress effects on meat quality

The most common meat quality defect attributed to antemortem stress in beef and lamb is the incidence of "dark cutting" lean. In this condition, long-term antemortem stress results in the depletion of muscle glycogen resulting in a high ultimate pH. Apple et al. (1995) subjected sheep to restraint and isolation stress or restraint and isolation stress concurrently with epidural blockade for 6 h before slaughter. Stressed animals had substantially higher plasma concentrations of epinephrine and cortisol throughout the 6-h stress treatment than non-stressed controls. The increase in glucocorticoid and catecholamine concentrations coincided with increased serum glucose and lactate concentrations. Additionally, serum concentrations of insulin were increased in stressed lambs 24 min following the onset of the restraint and isolation treatments. These results suggest that the treatments effectively induced a stress response, which mobilized glycogen stores for use in a "fight or flight" response to the stressor. When these animals were slaughtered, the stressed animals produced meat with higher pH at every postmortem time period measured during the first 24 h postmortem (Apple et al., 1995). The higher pH values in *M. longissimus lumborum et thoracis* muscles from stressed lambs were concomitant with decreased glycogen and lactate concentrations in these muscles at each sampling time. The stressed lambs had higher CIE L*, a*, and b* values in the *M. longissimus lumborum et thoracis* than the non-stressed controls. Additionally, chops from stressed lambs had lower Warner-Bratzler shear force values than those from non-stressed controls.

Currently available data on the relationship between antemortem stress and meat quality focus on variation in postmortem metabolism and ultimate pH. Geesink, Mareko, Morton, and Bickerstaffe (2001) reported that the *M. longissimus* from lamb carcasses with an intermediate ultimate pH (5.8 - 6.1) had Warner-Bratzler shear force values that were much higher than muscles with higher or lower ultimate pH values. Beltrán, Jaime, Santolaria, Sanudo, Alberti, and Roncales (1997) reported that high ultimate pH in beef carcasses associated with antemortem stress was associated with increased m-calpain activity and greater tenderness.

Lowe, Devine, Wells, and Lynch (2004) examined the relationships between urinary catecholamines measured at slaughter, ultimate muscle pH, and shear force in bulls and cows. Those investigators reported that non-mixed bulls had greater glycolytic potential, lower urinary epinephrine levels, and lower shear force values at 20 and 90 h postmortem than their commingled counterparts. Additionally, increased urinary concentrations of epinephrine were associated with decreased glycolytic potential values. Muscle pH and shear force appeared to have a quadratic relationship. Steaks with low pH values (below 5.7) had relatively low shear force values. Increasing muscle pH to approximately 6.0 produced higher shear force values. Muscles with pH greater than 6.0 had shear force values similar to those with pH values below 5.7. Interestingly, when the authors removed data derived from muscles with ultimate pH values greater than 5.7 were removed from the statistical analysis, the mean shear force for the commingled bulls still tended to be higher than the mean shear force observed for the non-mixed bulls (Lowe et al., 2004).

Jeremiah, Newman, Tong, and Gibson (1988) assigned steers and bulls to either a minimal stress treatment (transported 4 km to processing plant and slaughtered within 4 h) or normal stress treatment (transported 160 km to processing plant and slaughtered up to 24 h later). Sensory panel tenderness ratings for *M. longissimus lumborum* samples from bulls did not differ between stress treatments. *M. longissimus lumborum* samples from steers exposed to the greater stress treatment received initial and overall tenderness ratings that were similar to those given to samples taken from the bull carcasses. However, samples from steers assigned to the lesser stress treatment received higher tenderness ratings than the samples from carcasses assigned to the other treatments. This is consistent with the observations of Jones, Schaefer, Tong, and Vincent (1988) regarding the fasting and transport of slaughter cattle. There also was a shift in the acid-base balance in the animals exposed to fasting and transport treatments (Schaefer et al., 1988).

When scientists apply stressors as treatments, differentiating the effects of antemortem stress on tenderness from the effects due strictly to muscle pH is difficult. However, it is possible that stress response caused by common management practices may have a negative impact on meat tenderness independent of muscle pH. Additionally, it is difficult to assess the effects of the stressors applied as treatments because sample collection may be stressful to control animals.

2.3. Animal temperament

Animal behavior is a factor of concern in production environments because behavior is related to the ease and safety with which the animals can be handled. As animal welfare is increasingly scrutinized, temperament will receive greater emphasis.

Additionally, temperament affects productive efficiency (Burrow & Prayaga, 2004), reproductive traits (Hammond et al., 1996), and meat quality (Vann et al., 2004). The effect temperament has on these traits appears to be mediated through increased stress responsiveness in these animals with excitable temperaments. Research on human subjects suggests that individuals with greater responsiveness to stressful situations neurologically responded with the right prefrontal cortex, while those with lesser responsiveness responded with the left prefrontal cortex (Rosenkranz et al., 2003). The neurological response seemed to be related to variation in the activation of the adrenal axis, which subsequently adversely affected the production of antibodies in response to an immune challenge. Previous research with cattle has indicated strong relationships between animal temperament and stress responsiveness (Curley, 2004). Cattle with more excitable temperaments also had more extensive responses to CRH or ACTH challenges. Excitable cattle also had higher basal concentrations of circulating glucocorticoids, which suggests a chronic state of activation of the HPA axis. Repeated exposure to acute stressors does not consistently result in diminished response to the stressor (Minton, 1994). This is in agreement with the findings of Grandin (1993a), who reported that displays of calm or agitated behavior during restraint were consistent in repeated restraint sessions. Therefore, it appears that animals prone to large stress responses will not acclimate to stressors over time. Therefore, animals with excitable temperament may exhibit altered metabolism compared to their calmer counterparts, which may alter their productive efficiency and meat quality characteristics.

Animal temperament is most commonly assessed by subjectively rating the animals' behavior during its interactions with humans. Methods that have been used includes evaluating the animals' reaction to handlers in the holding pens as the animals are worked (Hammond et al., 1996) and behavior while standing in the working chute (Grandin, 1993a). Flight distance has been used as a measure of the animals flight zone (Grandin, 1980), although this measure is difficult and time consuming to assess (Burrow, Seifert & Corbet, 1988). The subjective nature of these methods makes them dependent on the consistency of the evaluators. Additionally, reactions to handling and flight zones may be affected by events encountered by the animal immediately before the evaluation. To provide more objective measures of temperament, Burrow et al. (1988) proposed a system that measures the speed at which the animals leave the working chute. This measure was moderately to highly heritable ($h^2 = 0.54$) at weaning, but lower heritability ($h^2 = 0.26$) was noted at 18 mo of age.

Measures of temperament change over time. Burrow et al. (1988) found no difference in exit velocity between bulls and heifers at weaning, but the heifers had slower velocities than the bulls at 18 mo of age. The bulls in that study had been handled more intensively than the heifers, which suggests that increasing experience with increased age may affect temperament measures. This is consistent with the reports of Falkenberg et al. (2005), who reported exit velocities taken late in the feeding period to be slower than those taken earlier. Curley (2004) reported that exit velocities of Brahman bulls classified as temperamental decreased in subsequent evaluations taken 60 d apart. However, bulls classified as Intermediate or Calm showed no similar decrease. Grandin (1993b, 1997) stated that animals will become habituated to non-aversive handling over time. This was confirmed by Becker and Lobato (1997), who found that calves that had been exposed to gentle handling showed more inquisitive behavior, handled more quickly, and attempted fewer escapes than those that had not been handled. Earlier, Grandin (1993a) reported displays of agitation to be consistent during repeated restraint sessions at 30-d intervals (5 total sessions). The collective results of these studies suggest that the values for various temperament indicators decrease over time, but the relative rankings within contemporary groups are consistent.

2.4. Temperament effects on meat quality

Voisinet et al. (1997a) assigned chute scores to feedlot steers as they were handled at the feeding facility. Those authors reported that a greater percentage of excitable cattle displayed borderline dark cutting lean than less temperamental animals and steaks from the carcasses of excitable cattle had higher Warner-Bratzler shear force values than those from calmer animals. Animals with excitable temperaments were noted to have lower average daily gains than those with calmer temperaments (Voisinet, Grandin, Tatum, O'Connor, & Struthers, 1997b). Wulf, O'Connor, Tatum, and Smith (1997) reported that chute scores were positively correlated with 24-h calpastatin activity and Warner-Bratzler shear force values ($r = 0.35$ and 0.49, respectively) and negatively correlated with average daily gain, final live weight, carcass weight, and CIE L* and b* values ($r = -0.58, -0.34, -0.24 –0.34$, and $–0.23$, respectively). Vann et al. (2004) reported a low-to-moderate relationship has been observed between exit velocity and pen scores and Warner-Bratzler shear force ($r = 0.24$ to 0.35).

Falkenberg et al. (2005) evaluated exit velocity in feedlot steers at weaning, on arrival at the feedlot, and again immediately before slaughter. Those investigators found that exit velocity measured at weaning was negatively correlated to average daily gain ($r = -0.28$) and positively correlated to Warner-Bratzler shear force ($r = 0.29$).

Additionally, those authors found that increasing exit velocity was associated with lighter carcass weights. Interestingly the relationships between exit velocity and all other factors was strongest at weaning. Taking exit velocity later in the feeding period was far less effective in predicting meat quality attributes.

CHAPTER III

MATERIALS AND METHODS

3.1. Animal selection and handling

Steers (n = 144) were selected to evaluate the relationship between animal temperament and stress responsiveness to feedlot performance, carcass merit, and meat quality. These animals were obtained from research herds that previously had been used in temperament and stress responsiveness experiments. Therefore, it was believed that sufficient variation in these traits would be present to test the stated hypotheses. The cattle differed in biological type and were subjected to dissimilar management protocols before being included in this study. Due to concerns that these pre-existing factors might affect the results of the present study, we segregated the cattle into three contemporary groups. Other than the differences between the contemporary groups described later, the cattle were managed similarly between the three contemporary groups.

This study was designed to test the effects of temperament and stress responsiveness on feedlot cattle fed and managed under commercial conditions. The cattle were fed at two feedlots to accommodate scheduling and pen availability. The feedlots were located approximately 100 km apart and climate differences were minimal. With the exception of data collection procedures, all cattle used in this trial were handled in a similar manner as others being fed in the same feeding facility. Management decisions were made at the discretion of the feedlot manager. All cattle were fed to a target fat thickness endpoint of approximately 1.3 cm, as estimated by the feedlot managers.

The cattle in the first contemporary group consisted of Bonsmara-sired yearling steers (n = 31) raised at the Texas Agricultural Experiment Station in Overton. cattle were removed from pasture, weighed, and held with access to water for 12 h before being transported approximately 700 km to the King Ranch South feedlot, Kingsville, TX. The second contemporary group consisted of Angus-sired yearling steers (n = 49) obtained from the Brown Loam facility of the Mississippi Agricultural Experiment Station. These steers previously had been part of a corn grazing study. The steers were transported approximately 1,050 km to the Hondo Creek Cattle Company feedlot in Edroy, TX.

The third contemporary group consisted of calf-fed steers raised at the Brown Loam facility of the Mississippi Agricultural Experiment Station. Angus-sired steer calves (n = 48), were weaned and backgrounded for approximately 40 d. The calves then were weighed before being transported approximately 1,090 km to the King Ranch South feedlot facility in Kingsville, TX.

3.2. Assessment of temperament

Measures of disposition and stress responsiveness were obtained when the cattle were weighed before shipment, upon arrival at the feedlot, at approximately 70 d on feed, and before to transport to the processing facility. At the feedlot, the cattle were implanted, vaccinated, and placed on feed according to the standard practices of the facility The Bonsmara-sired calves were implanted once, on arrival at the feedlot with Component E-C® and received no further growth promotants. The Angus-sired yearling-fed steers received a Revalor-S® implant on arrival at the feeding facility. The Angus-sired calf-fed steers received a Component E-C® on arrival at the feedlot and were re-implanted with Component TES® after approximately 70 d on feed. None of the contemporary groups received implants within 100 d of slaughter.

The disposition of the animals was evaluated by measuring exit velocity. Exit velocity was measured as the cattle left the working chute (Burrow et al., 1988; Figure 1). A pair of infrared eyes connected to an electronic timing unit (Farm Tec Inc., North Wylie, TX) was placed approximately 1 m in front the working chute. As the animal passed between the first pair of electronic eyes, a timer was started. The timer was stopped as the animal crossed a second set of infrared eyes placed 1.82 m beyond the first set of eyes. Exit velocity is reported in m/s.

Before shipment to the feeding facility, subjective behavior scores were assigned to each animal. These scores were not assigned during later evaluation times because the feedlot facilities were not conducive to collection of these data. As the animals moved through the facilities, an evaluator subjectively assigned chute scores based on the behavior of the animal as it stood in the weigh-box before being moved into the squeeze chute. The animal was not placed under any restraint other than the confinement to the weigh-box itself. The ratings were made after the head and tail gates were both shut. The scale was as follows: 1 = calm, no movement; 2 = slightly restless; 3 = squirming, occasionally shaking the squeeze chute; 4 = continuous, very vigorous movement and shaking of the squeeze chute; 5 = rearing, twisting of the body and struggling violently (Grandin, 1993a). Similarly, a pen score was determined in the holding pens of the working facility. A small group (4 to 5 animals) was placed in a small pen and the behavior of the animals was evaluated as the handler approached the group. The scale used for pen scores was as follows: 1 = walks slowly, can be

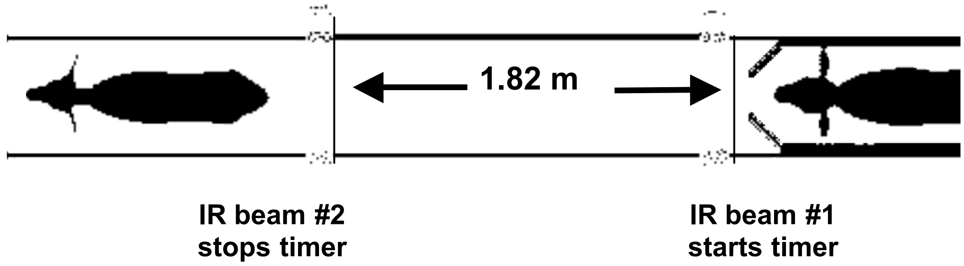

Figure 1. Schematic diagram of the measurement of exit velocity.
(adapted from Curley, 2004).

approached slowly, not excited by humans; 2 = runs along fences, stands in corner if humans stay away; 3 = runs along fences, head up and will run if humans come closer, stops before hitting gates and fences, avoids humans; 4 = runs, stays in back of the group, head high and very aware of humans, may run into fences and gates; 5 = excited, runs into fences, runs over anything in its path (Hammond et al., 1996).

3.3. Blood sample collection

Each time the animals were processed, blood samples were collected via tail venipuncture. Serum samples were collected in an evacuated blood collection tube with no added anti-clotting agents and held, in ice, to allow the blood to clot. Within 4 h, the tubes were rimmed with a wooden applicator to ensure the clotted blood was not attached to the tube and then centrifuged. The serum was aspirated into 12 × 75 mm plastic storage tubes and frozen (-80°C) until they were analyzed for cortisol. Cortisol was measured using a primary antibody assay procedure (Carrol, Willard, Bruner, McArthur, & Welsh, 1996). The primary antibody was rabbit anti-cortisol antiserum received at a dilution of 1:400 and diluted further to 1:2500 (Pantex, Santa Monica, CA, Cat. P#44). Standards (4-pregnen-11B, 21-tricol-3, 20-dione; Steroids Inc., Wilton, NH) were made by serial dilutions (4000 pg/500 µL to 3.9 pg/500 µL), and the tracer used was [1,2-^{3}H] Hydrocortisone (NEN, Boston, MA, Cat. #NET-185). The liquid scintillation fluid was Ecolume (ICN, Irvine, CA, Cat. #882470). The assay sensitivity was 62 pg/assay tube and the antibody cross-reacted 60, 48, 0.01 and 0.01% with corticosterone, progesterone and estradiol, respectively. Intra- and inter-assay coefficients of variation were 8 and 12%, respectively.

3.4. Slaughter and carcass data collection

When the feedlot manager determined the animals had reached the appropriate fat thickness endpoint, cattle were transported approximately 70 km to the processing facility. Steers were converted to carcasses via industry standard procedures within 4 h of arriving at the facility. Carcasses were subjected to high-voltage electrical stimulation during a 27 s period (9 s per each of three stimulating bars) immediately before evisceration. The first and second stimulating bars administered 328 V (AC) at 1.9 amps while the third bar administered 204 V (AC) at 3.0 amps. Carcasses were chilled for 48 h in a -3°C cooler. Spray-chilling was used intermittently for 8 h, beginning approximately 4 to 6 h after the carcasses had entered the chilling cooler. Forty-eight h postmortem, carcasses were ribbed at the 12^{th}-13^{th} rib interface and allowed to bloom for at least 15 min before carcass merit measurements were taken as described later.

Because antemortem stress is likely to affect postmortem muscle metabolism, muscle pH and temperature were recorded at 0.5, 4, 7, 12, 24, and 48 h postmortem. These times were selected because access to the carcasses was limited immediately postmortem, and these times proved to be the most feasible for consistent data collection. Due to equipment failure, pH was not measured on the calf-fed Angus steers after 12-h postmortem. However, carcass temperature was collected at all of the scheduled times. At 48 h postmortem, the carcasses were ribbed at the 12^{th}-13^{th} rib interface and allowed to bloom for approximately 15 min. USDA (1996b) yield and quality grade factors were determined by trained Texas A&M University personnel. Additionally, CIE L*, a*, and b* color space values were measured using a Hunter Miniscan XE colorimeter (HunterLabs, Reston, VA; Illuminant A; 10° observer).

Following grading, the carcasses were fabricated. The beef, loin, strip loin (IMPS # 180; NAMP, 1997; USDA, 1996a) was retrieved from the right side of each carcass, packed, with ice, in insulated containers, and transported to the Rosenthal Meat Science and Technology Center at Texas A&M University. Each strip loin was cut into 2.54 cm steaks, which subsequently were vacuum packaged and assigned to aging treatments or used for measurement of sarcomere length, 72-h calpastatin activity, and fat and moisture. Animal and location identity were maintained for all steaks. From the cranial aspect of the *M. longissimus lumborum*, the first steak was assigned to fat and moisture determination. The second, third, fourth, and fifth steaks were assigned randomly to be aged for 3, 7, 14 or 21 d before Warner-Bratzler shear force measurements were determined. After the appropriate aging times, the steaks were frozen at -20°C until further analysis. The sixth and seventh steaks were assigned to sarcomere length determination and 72-h calpastatin assays, respectively.

3.5. Sarcomere length

Sarcomere length was determined on three samples from each steak representing the lateral, center, and medial portions of that steak. Sarcomere lengths were measured on ten muscle fibers from each sample. Sarcomere length of the sample was reported as the mean value obtained from the ten muscle fibers. Sarcomere length for the steak was reported as the mean value obtained from the three samples. Approximately 5 g of minced muscle tissue was removed from each sample designated for sarcomere length determination. The sample was homogenized in buffer (25 *mM* sucrose, 0.2 *mM* KCl; pH 7.0). Drops of homogenate were placed on glass microscope slides and covered with a cover slip. Sarcomere length was measured with a He-Ne laser according to the procedure prescribed by Cross, West, and Dutson (1981). The muscle fibers were passed through the beam of a He-Ne laser (γ = 0.6328 nm). The distance between the two first-order diffraction bands was measured (mm). Sarcomere length was calculated using the following equation:

$$\textit{Sarcomere length}, \mu m = \frac{0.6328 \times D \times \sqrt{(T/D)^2 + 1}}{T}$$

D = Distance from the sample to the diffraction pattern screen.

T = Half the distance between the first order diffraction bands in mm.

0.6328 = the wavelength of the laser.

2.6. *Fat and moisture content*

The steak designated for fat and moisture analysis was snap-frozen in liquid nitrogen and pulverized in a Waring blendor. Approximately 3 g of powdered sample was weighed into a pre-dried filter-paper thimble and used to determine the fat and moisture content of the muscle by the oven drying and ether extraction procedure (AOAC, 1990).

3.7. Calpastatin assays

Calpastatin activity was determined at 72 h postmortem. This time was selected because the distance between the processing facility and our laboratory, coupled with the large number of samples needing to be processed, prohibited earlier samples from being handled appropriately. Additionally, this sample coincided with the 3-d aging time used for Warner-Bratzler shear force analysis. Calpastatin samples were extracted and purified according the procedures of Shackelford, Koohmaraie, Cundiff, Gregory, Rohrer, and Savell (1994), as modified by Koohmaraie, Shackelford, Wheeler, Lonergan, and Doumit (1995). A 10-g sample was extracted in 30 mL of a 100 *mM*

Tris, 20 *mM* EDTA buffer (pH 8.3) with 0.05% MCE, 100 mg/L ovomucoid, 6 mg/L leupeptin, and 2 *mM* PMSF. The sample was homogenized via three 30-s bursts in a Waring blendor with 30-s resting periods between each burst. The homogenates were centrifuged at 35,000 × g before the extracts were dialyzed against 40 *mM* Tris/HCl, 5 *mM* EDTA, and 0.05% MCE (pH 7.35). Following dialysis, the extracts were heated to 95°C in a water bath for 15 min and centrifuged at 35,000 × g for 60 min. The supernate was loaded on 10 ml DEAE Sephacel and washed with 100 mL elution buffer containing 25 mM NaCl. Nine 5 mL fractions were eluted with elution buffer containing 200 mM NaCl. Each fraction was screened for the presence of calpastatin. Those fractions displaying calpastatin activity were pooled and dilutions were assayed for calpastatin activity according to the procedures of (Koohmaraie, 1990).

3.8. Cooking and Warner-Bratzler shear force determination

Steaks designated for Warner-Bratzler shear force determinations were cooked to an internal temperature of 70˚ C on a clam-shell type grill (model GGR62, Salton, Inc., Lake Forest, IL) according to the procedures of McKenna, King, and Savell (2004). Internal temperature was continually monitored using type K thermocouples (model KTSS-HH, Omega Engineering, Inc., Stamford CT) attached to a Thermocouple Input Benchtop Meter (model BS 6001A, Omega Engineering, Inc., Stamford, CT). Following cooking, the steaks were chilled overnight at 4˚ C and six 1.27 cm cores were removed parallel to the muscle fiber orientation. Cores were sheared on a Universal Testing Machine (model SSTM-500, United Calibration Corp., Huntington Beach, CA) equipped with a V-notch Warner-Bratzler blade, and a 50 kg compression load cell with a cross-head speed of 200 mm/min. Additionally, cook time and cooking losses were recorded.

3.9. Statistical analysis

Temperament indicator data were used to segment individual animals into one of three groups: Exit velocities and pen scores collected at pre-shipment evaluations were combined to create a temperament index. Temperament index was calculated using the following equation:

$$Temperament\ \ index = \frac{(exit\ velocity + pen\ \ score)}{2}$$

At each subsequent sampling time, the cattle were evaluated with regard to exit velocity because pen score data were not available. These temperament data were used to segregate the cattle into temperament categories as described later to address particular issues of concern.

At each evaluation, the cattle were ranked within their contemporary group. The rankings obtained at each sampling time were averaged to obtain a mean temperament ranking. The mean ranking was used to segment animals into temperament categories so that the numbers of animals in each temperament category were similar to those reported by King et al. (2005).

Carcass characteristic, meat tenderness, and meat quality trait data were compared across these categories using the Proc MIXED procedure of SAS (SAS Institute, Cary, NC). It was expected that the three contemporaries groups might differ with regard to muscle tenderness, so the model tested the main effects of temperament category and contemporary group as well as their interaction. Exit velocity, body weight, and serum cortisol data were analyzed as repeated measures. Additionally, muscle pH and temperature decline data were analyzed as repeated measures using the Proc MIXED procedure of SAS. Because the temperament category × time interaction was of particular interest for pH decline, the simple effects of temperament category at each postmortem time was tested using the SLICE option as described by Littel, Miliken, Stroup, and Wolfinger (1996). When the SLICE option results indicated that the simple effects were statistically significant, the appropriate least-squares means were compared using linear contrasts. Warner-Bratzler shear force and cooking trait data were analyzed as a split-plot design. The whole-plot factors were temperament classification and contemporary group. The sub-plot factor was aging time. Pearson correlation coefficients and partial correlation coefficients were generated to examine the relationships between temperament traits, meat quality traits and Warner-Bratlzer shear force using the PROC CORR and PROC GLM procedures of SAS, respectively

The effectiveness of a single temperament evaluation in sorting cattle into groups with regard to carcass and tenderness traits was of interest. Consequently, the same temperament measurements were used to sort the cattle into groups before shipment to the feedlot, on arrival at the feedlot, and after approximately 70 d on feed. Those animals more than one standard deviation higher or lower than the mean for their contemporary group were designated as Excitable and Calm, respectively. Those animals with values within one standard deviation of the mean were assigned to the intermediate group. Because our initial analysis indicated that temperament category affected yearling-fed and calf-fed animals differently, the data concerning yearling-fed and the calf-fed animals were analyzed separately. Additionally, the temperament categorization at each sampling time were conducted independently (i.e., previous knowledge of temperament was ignored). The models used in these analyses were similar to those described earlier, except that contemporary group was used as blocking factor for the yearling-fed animals.

For all analyses, least-squares means were generated for all significant interactions and main-effects not involved in higher order interactions. When appropriate these means were separated using the PDIFF option. A pre-determined probability of Type I error (α) of 0.05 was used for judgments for statistical significance.

CHAPTER IV

RELATIONSHIPS BETWEEN TEMPERAMENT AND MEAT QUALITY

The distribution of animals within each contemporary group classified as Calm, Intermediate, or Excitable are presented in Table 1. The three contemporary groups in this study were not included to compare specific breed types or production systems, but rather to compare the relationships between temperament and quality endpoints under varying production conditions. Previous experience with measures of temperament has suggested that the anticipated negative effects of temperament on productive traits are observed in the extreme cases (Curley, 2004). A visual appraisal of the data indicated that several animals were redistributed between the extreme temperament categories and the intermediate group at successive evaluations. In an attempt to identify the animals that were consistently on the extremes of their contemporary group, the animals were ranked, within their contemporary group, at the pre-shipment, arrival, and midpoint evaluation times and then were classified into temperament categories based on the mean ranking of the animal. The number of animals assigned to each temperament category was approximately equal to those reported in King et al. (2005) and was intended to identify the animals that consistently exhibited extremely high or low excitability in response to handling while providing sufficient numbers in each group for statistical analysis.

4.1. Animal temperament

Temperament classifications were assigned within the three contemporary groups based primarily on exit velocities measured before shipment to the feedlot, upon arrival at the feedlot, and after approximately 70 d on feed. Due to this method of

Table 1
Distribution of animals from three contemporary groups stratified into temperament categories

Contemporary group	Temperament category			Total
	Calm	Intermediate	Excitable	
Bonsmara Yearling-fed	5	20	7	31
Angus Calf-fed	7	30	12	49
Angus Yearling-fed	10	29	9	48
Total	22	79	28	128

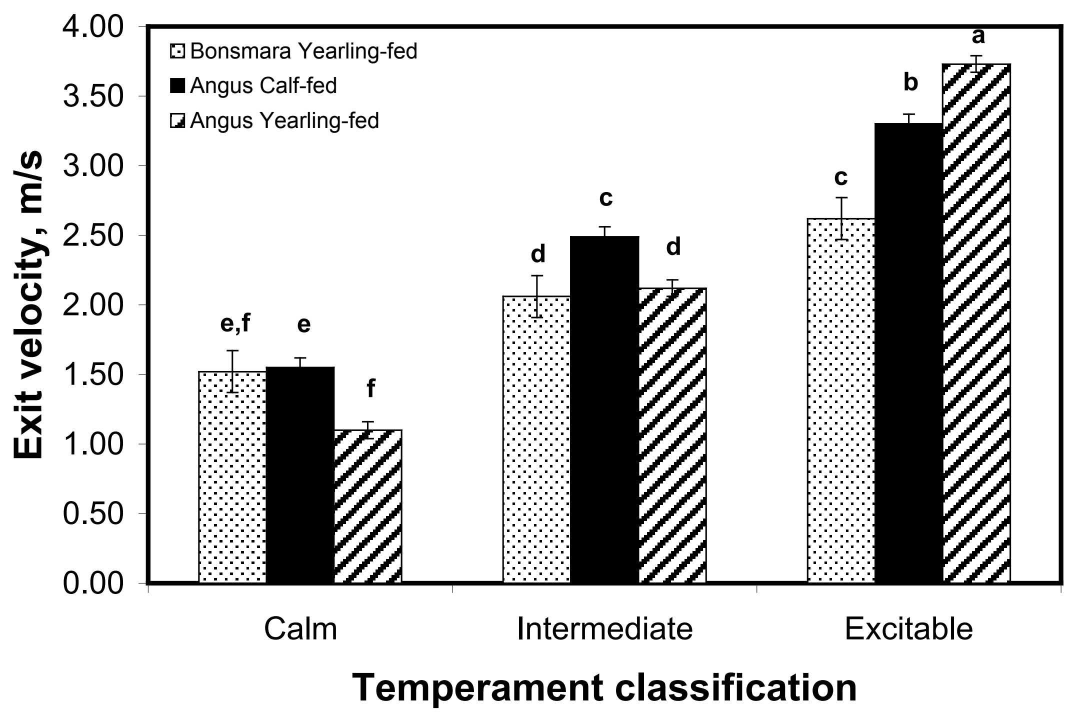

Figure 2. Least-squares means for the exit velocity of feedlot steers fed in three contemporary groups and stratified into three temperament categories. (RMSE = 0.43; Interaction *P* < F = <0.001).

classification, it was expected that the temperament categories would differ with respect to exit velocity. An interaction was observed between temperament classification and contemporary group (Figure 2). In general, the yearling-fed Angus-sired steers had greater differentiation between temperament categories than the other two groups. This is particularly evident in that the Excitable Angus yearling-fed steers had the highest ($P < 0.05$) exit velocities. Additionally, the yearling-fed Angus steers classified as Calm had the lowest ($P < 0.05$) exit velocities. In contrast, the smallest magnitude of difference in exit velocity between temperament categories was observed in the Bonsmara-sired yearling-fed steers. However, the differences in exit velocity among temperament categories in steers were statistically significant. The Intermediate Angus-sired calf-fed group had higher ($P < 0.05$) exit velocities than the Intermediate cattle from the other groups.

Exit velocities were slower ($P < 0.05$) at the midpoint sampling than before shipment to or on arrival at the feeding facility (Figure 3). This may reflect an adaptation or learning behavior in these animals as they gained experience with being handled. The hypothesis that animal temperament influences productive efficiency, immune capacity, and ultimately meat quality is predicated upon the relationship between temperament and the stress responsiveness of the animal. Measures of temperament are used in this capacity as a predictor of the animal's physiological response to novel experiences. Therefore, the apparent learning behavior would suggest that later measures of temperament would have less predictive value than those measured earlier in production. Becker and Lobato (1997) reported that Zebu-cross

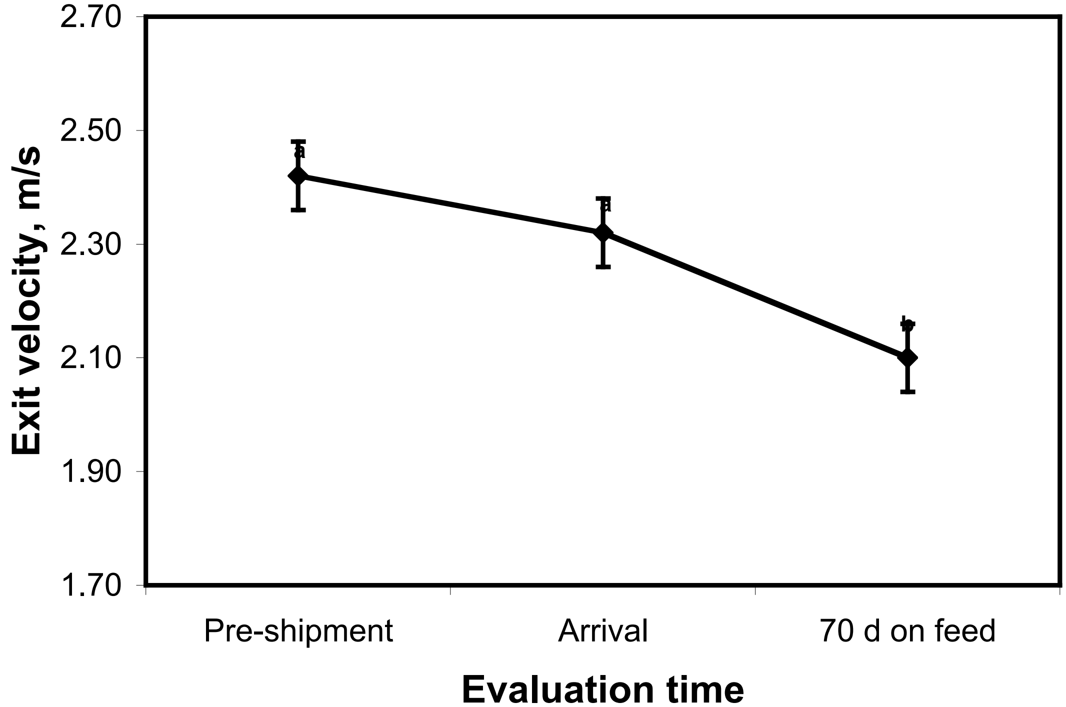

Figure 3. Least-squares means for exit velocity measured at three evaluations during the feeding period.

Table 2
Least-squares means for temperament traits of feedlot steers fed in three contemporary groups

Trait	Contemporary group			RMSE	*P* > F
	Bonsmara yearling-fed	Angus calf-fed	Angus yearling-fed		
Pre-shipment pen score	2.09c	2.55b	2.91a	0.71	<0.01
Pre-shipment chute score	1.36b	1.65b	1.96a	0.59	<0.01
Pre-shipment temperament index[a]	3.37a	2.52b	2.63b	0.37	<0.001

[a]Temperament index = (exit velocity + pen score)/2.
Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

calves that previously had been handled gently attempted to escape less, displayed less aggression, and more inquisitive behavior than their counterparts that had not been handled. Our findings of reduced exit velocity at later evaluations are consistent with the observations of Falkenberg et al. (2005), who also observed reduced correlations between exit velocity and production and meat quality traits when the exit velocities were measured later in production. Curley (2004) noted only minimal changes in the magnitude of three exit velocity measurements taken 60 d apart on Brahman bulls with calm and intermediate temperaments. However, the bulls with excitable temperament showed a reduction in exit velocity during the first 60-d interval comparable to that seen in the present study.

Before shipment to the feedlot, animal temperaments were also evaluated using pen scores assigned in the holding facilities before they were moved through the chute. Pen scores and exit velocities measured before shipment to the feeding facility were combined to create temperament indexes, which were used in conjunction with later exit velocity measurements to segment the steers into temperament classifications. Chute scores were assigned as the steers stood in the weigh box before being moved to the squeeze chute. The contemporary group by temperament category interaction was not a source of variation for any of these traits. The least-squares means for the contemporary group and temperament classification main effects are presented in Table 2 and Table 3, respectively. Pen scores were highest ($P < 0.05$) in the Angus-sired yearling-fed steers, and lowest for the Bonsmara-sired yearling-fed steers. The Angus-sired calf-fed steers were intermediate with respect to pen score. Chute scores were higher ($P < 0.05$) in the Angus-sired yearling-fed steers compared to the other two groups. In contrast, the

Table 3
Least-squares means for temperament traits of feedlot steers stratified into temperament categories

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Pre-shipment pen score	1.59c	2.38b	3.57a	0.71	<0.001
Pre-shipment chute score	1.43	1.66	1.87	0.59	0.14
Pre-shipment temperament index[a]	1.83c	2.79c	3.89b	0.37	<0.001
Cortisol ng/mL	10.18c	11.91b	14.99a	35.19	<0.001

[a]Temperament index = (exit velocity + pen score)/2.
Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

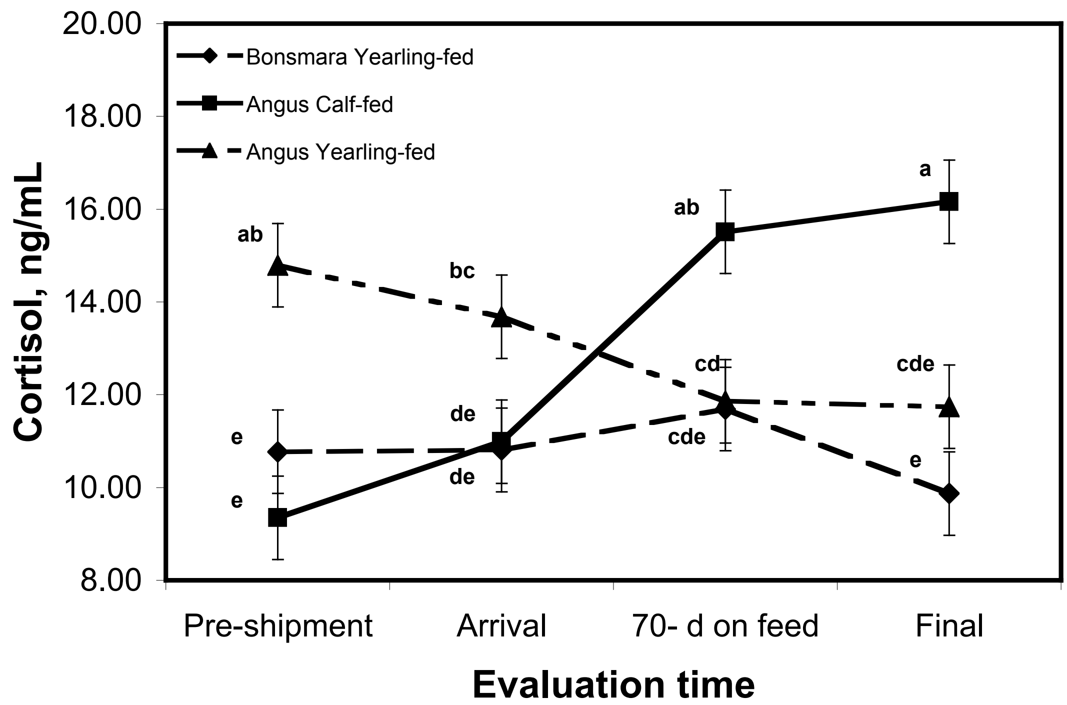

Figure 4. Least-squares means for the serum cortisol concentrations of feedlot steers fed in three contemporary groups and stratified into temperament categories. (RMSE = 35.19; Interaction $P > F = < 0.01$).

Bonsmara-sired yearling-fed steers had the highest ($P < 0.05$) temperament index values compared to both groups of Angus-sired steers, which did not differ.

As described earlier, pen scores and exit velocities measured before shipment to the feedlot were combined into temperament index values and used to sort the cattle into temperament categories. Therefore, by design, pen scores and temperament index values differed ($P < 0.05$) widely between temperament categories. Chute scores were not different between the three temperament categories. Chute scores numerically ranked the temperament categories appropriately, but did not provide sufficient differentiation to be statistically different. The finding that chute scores were least effective in differentiating animals according to temperament is consistent with the observations of Curley (2004), who compared chute scores, pen scores, and exit velocities in relation to serum cortisol concentrations. In contrast, Wulf et al. (1997) and Voisinet et al. (1997a,b) used chute scores to sort cattle in to temperament categories and found strong relationships between these groupings and meat quality endpoints. Perhaps the differing predictive capacity of chute scores are due to the previous experience of the animals. Wulf et al. (1997) and Voisinet et al. (1997a,b) assigned chute scores to animals during routine handling in a commercial feedlot. Those investigators had no prior knowledge of the handling experiences of the animals. Because these animals were in commercial facilities it is likely that they had been commingled and had limited exposure to handling by humans. The chute scores in the present study were assigned on the farm. The animals had all been moved through the facilities used in this experiments on multiple occasions. Additionally, they were handled as contemporary groups (i.e., had not been mixed) throughout their lives. Perhaps the animals learned from their previous experiences that no harm would come to them during the handling process.

The temperament classifications were intended to separate animals into groups that differ in stress responsiveness. The three temperament categories differed with regard to serum cortisol concentrations with cortisol concentrations decreasing ($P < 0.05$) with decreasing excitability. Contemporary group and sampling time interacted to affect serum cortisol concentration (Figure 4). Cortisol concentrations at the pre-shipment evaluation were higher in the Angus yearling-fed steers than the other two groups. However, the cortisol concentrations were progressively lower at each subsequent evaluation in the Angus yearling-fed steers. The Bonsmara-sired yearling-fed steers and Angus-sired calf-fed steers had lower serum cortisol concentrations at the pre-shipment evaluation and on arrival at the feeding facility. Serum cortisol concentrations remained constant in the Bonsmara-sired yearling-fed steers at the midpoint and final sampling times. However, the amount of circulating cortisol increased dramatically in the Angus-sired calf-fed steers. Pre-shipment cortisol concentrations were intended to provide estimates of baseline levels of circulating cortisol concentrations. However, these values would have been influenced by the animal's experience in the days and hours immediately before the samples were taken. In comparison to these data, Curley (2004) reported only small decreases in the circulating cortisol levels in Brahman bulls measured 120 d apart. Curley (2004) also reported that animals classified as temperamental (based on exit velocity) had higher baseline cortisol levels, though the actual response to a CRH or ACTH challenge were of lesser magnitude than those classified as being calmer. Curley (2004) suggested higher cortisol concentrations in temperamental steers might indicate a state of chronic activation of stress response that limited the response to an acute stimulus.

Simple Pearson correlation coefficients and the partial correlation coefficients between the various temperament and stress responsiveness traits are presented in Table 4. Partial correlation coefficients also were calculated using a model that accounted for contemporary group effects. Removing the effects of contemporary group caused relatively little change in the observed correlation coefficients. This indicates that although the contemporary groups differed with regard to temperament traits, the relationships between these variables collected throughout the production chain were essentially constant. In general, the relationships between temperament measures decreased as the time interval between the collection of the measures increased. This phenomenon commonly is observed in repeated measures data. However, it also may be indicative of the adaptation or learning behavior exhibited by the cattle with extensive handling. Before shipment to the feed yard, both pen score and exit velocity were moderately correlated to the circulating cortisol concentrations. The relationships between exit velocity and pen scores measured before shipment and cortisol concentrations at 70 d on feed or immediately before shipment to the processing facility were lower, but still were present. This suggests that exit velocity and pen scores provide reliable estimates of stress responsiveness throughout production. Chute scores showed similar Pearson correlation coefficients to pre-shipment cortisol levels, but the partial correlation coefficient was much smaller and not statistically significant. In fact, the chute score had very few statistically significant

Table 4
Partial correlation coefficients (above the diagonal) and Pearson simple correlation coefficients (below the diagonal) for the relationships between temperament traits

	Pre-ship TI[a]	Pre-ship EV[b]	Pre-ship PS[c]	Pre-ship CS[d]	Pre-ship CORT[e]	Arrival EV[f]	Arrival CORT[g]	Mid-point EV[h]	Mid-point CORT[i]	Final CORT[j]
Pre-ship TI[a]	--	0.83^{z}	0.81^{z}	0.30^{z}	0.31^{z}	0.54^{z}	0.17	0.56^{z}	0.27^{y}	0.21^{x}
Pre-ship EV[b]	0.76^{z}	--	0.40^{z}	0.15	0.26^{y}	0.51^{z}	0.16	0.63^{z}	0.24^{y}	0.17
Pre-ship PS[c]	0.64^{z}	0.40^{z}	--	0.36^{z}	0.27^{y}	0.49^{z}	0.14	0.40^{z}	0.24^{y}	0.23^{y}
Pre-ship CS[d]	0.16^{x}	0.12	0.38^{z}	--	0.13	0.16	-0.08	0.07	0.13	-0.09
Pre-ship CORT[e]	0.22^{y}	0.23^{z}	0.24^{z}	0.20^{x}	--	0.29^{y}	0.31^{z}	0.26^{y}	0.37^{z}	0.30^{z}
Arrival EV[f]	0.38^{z}	0.45^{z}	0.44^{z}	0.14	0.16^{x}	--	0.35^{z}	0.61^{z}	0.13	0.19^{x}
Arrival CORT[g]	0.17^{y}	0.17^{x}	0.22^{y}	0.08	0.41^{z}	0.31^{z}	--	0.37^{z}	0.29^{y}	0.41^{z}
Mid-point EV[h]	0.36^{z}	0.49^{z}	0.36^{z}	0.16	0.10	0.46^{z}	0.31^{z}	--	0.33^{z}	0.35^{z}
Mid-point CORT[i]	0.30^{z}	0.36^{z}	0.27^{z}	0.07	0.24^{z}	0.17	0.29^{z}	0.31^{z}	--	0.46^{x}
Final CORT[j]	0.15^{x}	0.30^{z}	0.23^{z}	0.03	0.20^{y}	0.28^{z}	0.31^{z}	0.41^{z}	0.51^{z}	--

[a]Temperament index {(exit velocity + pen score)/2} determined before shipment to the feedlot,
[b]Exit velocity measured before shipment o the feedlot.
[c]Pen score determined before shipment to the feedlot.
[d]Chute score determined before shipment to the feedlot.
[e]Serum cortisol concentration immediately before shipment to the feedlot.
[f]Exit velocity measured on arrival at the feedlot.
[g]Serum cortisol concentration at arrival at the feedlot.
[h]Exit velocity measured after approximately 70 d on feed.
[i]Serum cortisol concentration measured after approximately 70 d on feed.
[j]Serum cortisol concentration measured immediately before shipment to the processing facility.
^{x} = $P < 0.10$; ^{y} = $P < 0.05$; ^{z} = $P < 0.01$.

relationships to other temperament variables. Final cortisol concentrations were most correlated to the exit velocity measured at approximately 70 d on feed.

4.2. Feedlot performance

The Angus calf-fed steers were much lighter at all of the evaluations than the other two contemporary groups (Figure 5). The Angus calf-fed steers were weaned and backgrounded for only 40 d before being placed in the feedlot. In contrast, the other two groups of cattle had been grown on grass pasture (Bonsmara-sired yearling-feds) or corn grazing (Angus-sired yearling-feds) and were much older when they were placed on feed. The Angus-sired calf-fed steers were fed 70 and 89 d longer than the Bonsmara- and Angus-sired yearling-fed steers, respectively, but did not reach live weights equal to the other two groups. The Angus-sired calf-fed steers likely would have attained the same BW as the other two groups had they been fed for a longer period.

The cattle classified as Excitable were lighter ($P < 0.05$) at each evaluation than the Calm or Intermediate groups (Figure 6). These differences were relatively small, but in large-scale operations, these differences could be of economic importance. The differences in live weight between the Excitable cattle and the cattle from each of the other two groups were consistent at each evaluation time. This indicates that the growth rates were essentially equal between temperament categories during the feeding period. This is consistent with the lack of differences in average daily gain observed throughout the feeding period (Table 5). However, average daily gain was numerically lower in the Excitable steers during the later portion of the feeding period. Because all of the animals within a given contemporary group were from a common herd and managed similarly, it would appear that the Excitable cattle gained slower before entering the feedlot.

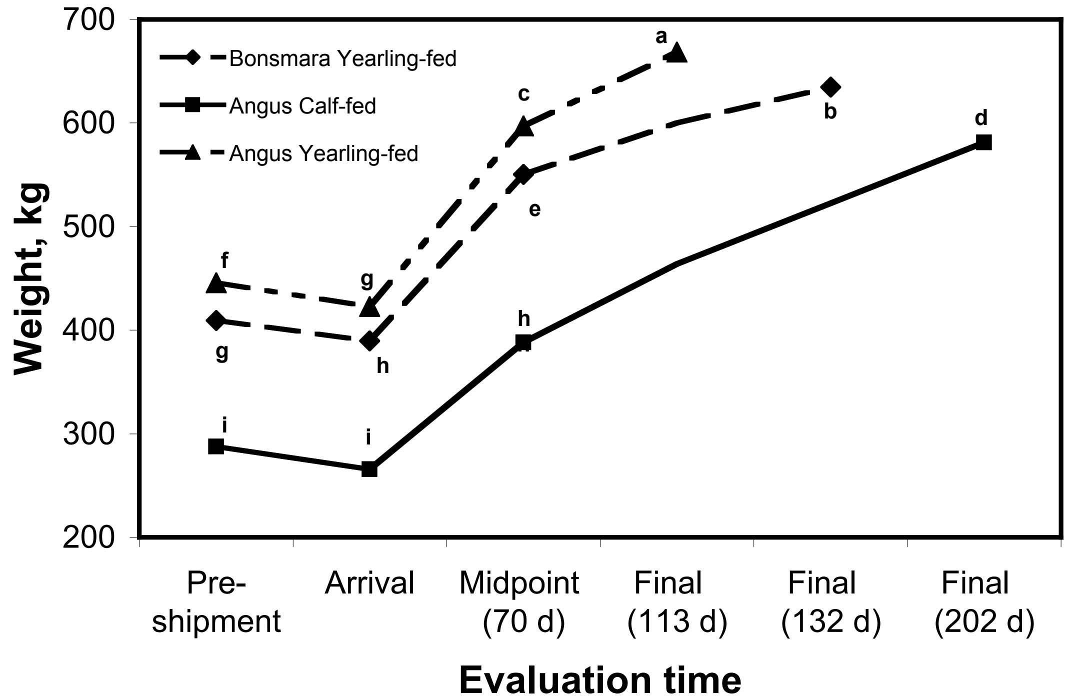

Figure 5. Least-squares means for body weights of feedlot steers fed in three contemporary groups measured at four evaluations during the feeding period.

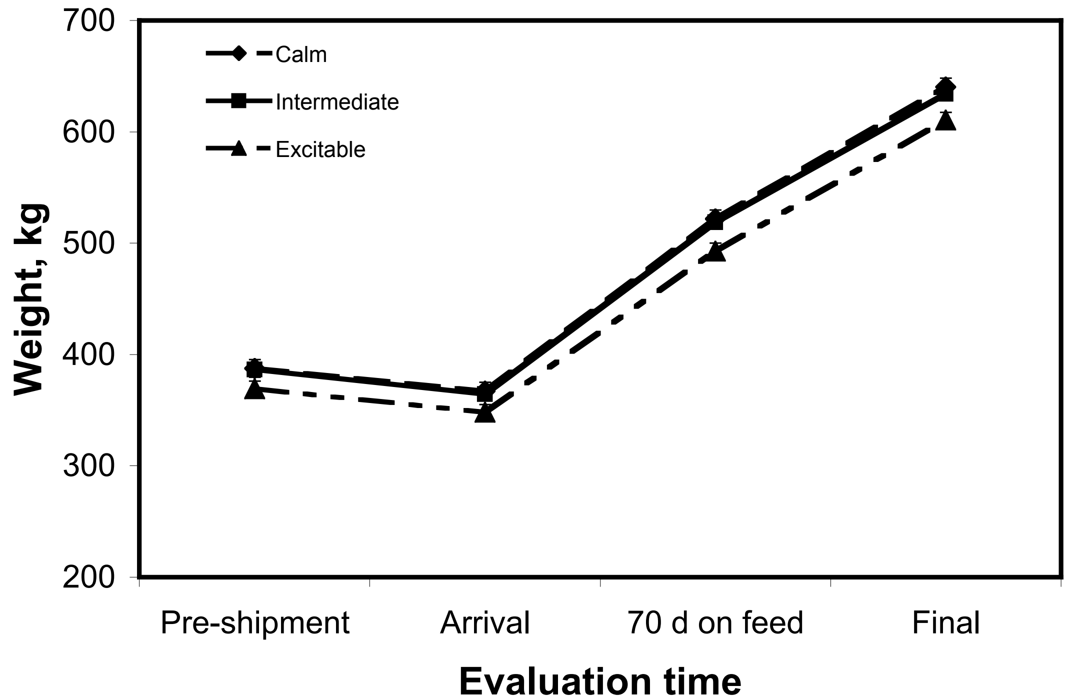

Figure 6. Least-squares means for body weights of feedlot steers stratified into temperament categories measured at four evaluations during the feeding period.

Table 5
Least-squares means for feedlot performance traits of feedlot steers stratified by temperament categories

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Shipping shrink, %	5.22	6.0	5.5	8.55	0.53
Average daily gain 1, kg/d	2.03	2.03	1.93	0.18	0.54
Average daily gain 2, kg/d	1.65	1.62	1.56	0.21	0.76
Average daily gain, total, kg/d	1.89	1.88	1.78	0.08	0.23
Dressing percentage, %	60.2	60.2	60.12	2.53	0.96

[a]Body weight lost during transport fo feeding facility.
[b]Average daily gain during first 70 d on feed.
[c]Average daily gain after 70 d on feed.
[d]Average daily gain during entire feeding period.
Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

Selection for increased 600-d weight using estimated breeding values has been reported to result in a correlated reduction in observed exit velocities within the population (Burrow and Prayaga, 2004). In contrast to our findings, Voisinet et al. (1997b) noted that lower chute scores were associated with higher average daily gains in cattle of both *Bos taurus* and *Bos indicus* genetics.

It was hypothesized that the weight lost by the animals during transport from the farm to the feeding facility would be greater in the Excitable steers than in steers with Calmer temperaments. However, this did not occur (Table 5). All of the contemporary groups underwent long transport times to the feedlot. Shrink may have approached a maximum in all of the animals due to the long duration of the transport.

The least-squares means for shipping shrink, average daily gain, and dressing percentage stratified by contemporary group are presented in Table 6. Shipping shrink was greater ($P < 0.05$) in the Angus-sired calf-fed steers than in either group of yearling-fed steers. This may have been because these steers were fed during a 40-d backgrounding period before being sent to the feeder. In contrast, the yearling-fed steers were gathered from their respective grazing pastures immediately before being sent to the feed yard. Thus, the calf-fed steers had more gut fill at the time of the pre-shipment weighing.

The Angus-sired yearling-fed steers gained faster during the first 70 d on feed than the Bonsmara-sired yearling-fed steers, which gained faster than the Angus-sired calf-fed steers during this period. The Angus-sired calf-fed steers had a relatively high incidence of respiratory disease during the first 70 d on feed (data not shown), which likely slowed their early gains. Average daily gain during the latter period did not differ

Table 6
Least-squares means for feedlot performance traits of feedlot steers fed in three contemporary groups

Trait	Contemporary group			RMSE	$P > F$
	Bonsmara yearling-fed	Angus calf-fed	Angus yearling-fed		
Shipping shrink[a], %	4.40b	7.27a	5.01b	8.55	<0.001
Average daily gain 1[b], kg/d	2.06b	1.45c	2.47a	0.18	<0.001
Average daily gain 2[c], kg/d	1.54	1.60	1.70	0.21	0.29
Average daily gain, total[d], kg/d	1.84b	1.54c	2.17a	0.08	<0.001
Dressing percentage, %	59.5b	59.8b	61.3a	2.53	<0.001

[a]Body weight lost during transport to feeding facility.
[b]Average daily gain during first 70 d on feed.
[c]Average daily gain after 70 d on feed.
[d]Average daily gain during entire feeding period.
Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

between contemporary groups. When average daily gains were calculated over the entire feeding period, the differences mirrored those observed during the first 70 d. The Angus-sired yearling fed steers had higher dressing percentages than either of the other two groups. The cause of this difference in dressing percentage is not readily apparent.

4.3. Carcass characteristics

Carcass characteristics differed substantially between the three contemporary groups. Both groups of yearling-fed steers produced heavier carcasses than did the calf-fed steers (Table 7). This is consistent with the observations of heavier final live weights in the yearling-fed steers. The yearling-fed steers had greater *longissimus* muscle areas, less adjusted fat thicknesses, and less estimated kidney, pelvic, and heart fat, and lower USDA yield grades than the calf-fed steers. The Angus-sired yearling-fed steers had greater fat thicknesses and USDA yield grades than the Bonsmara-sired yearling fed steers. The slaughter dates were scheduled when visual appraisal indicated that the mean adjusted fat thickness of the cattle was 1.3 cm. Some of the differences in adjusted fat thickness between the contemporary groups may be attributed to error in the visual estimates. May et al. (2000) reported that expert live evaluators' estimations of fat thicknesses were highly correlated ($r = 0.70$) with actual fat thickness. The evaluators in that study over-estimated fat thickness by 0.13 cm. The Angus-sired yearling-fed steers had greater marbling scores and USDA quality grades than the Angus-sired calf-fed steers. Both of these groups had higher marbling scores and USDA quality grades than the Bonsmara-sired steers. In agreement with the present findings, Wheeler, Shackelford, and Koohmaraie, (2004) reported Bonsmara-sired progeny produced lighter

Table 7
Least-squares means for carcass traits of feedlot steers fed in three contemporary groups

Trait	Contemporary group			RMSE	*P* > F
	Bonsmara yearling-fed	Angus calf-fed	Angus yearling-fed		
Hot carcass weight, kg	379b	348c	408a	1230	<0.001
Adjusted fat thickness, cm	1.43b	1.73a	1.55b	0.11	<0.001
Longissimus muscle area, cm^2	94.76a	82.29b	94.31a	81.71	<0.001
Estimated kidney, pelvic, and heart fat, %	1.78b	2.17a	1.96b	0.19	<0.001
Yield grade	2.73c	3.46a	3.15b	0.35	<0.001
Lean maturity[a]	148c	160b	172a	131	<0.001
Skeletal maturity[a]	165	164	163	153	0.84
Overall maturity[a]	159b	162b	167a	65	<0.001
Marbling score[b]	353c	429b	462a	5660	<0.001
Quality grade[c]	650c	698b	717a	1370	<0.001

[a]100 = A^{00}; 200 = B^{00}.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$.
[c]600 = $Select^{00}$; 700 = $Choice^{00}$.
Least-squares means within a row with different letters (a-c) differ (*P* < 0.05).

Table 8
Least-squares means for carcass traits of feedlot steers stratified by temperament categories

Trait	Temperament category			RMSE	*P* > F
	Calm	Intermediate	Excitable		
Hot carcass weight, kg	386	380	369	1230	0.20
Adjusted fat thickness, cm	1.60	1.62	1.49	0.11	0.22
Longissimus muscle area, cm^2	90.21	90.87	90.28	81.71	0.93
Estimated kidney, pelvic, and heart fat, %	1.96	2.01	1.95	0.19	0.79
Yield grade	3.22	3.17	2.96	0.35	0.23
Lean maturity[a]	162	158	160	131	0.32
Skeletal maturity[a]	164	164	164	153	0.97
Overall maturity[a]	164	162	162	64.86	0.63
Marbling score[b]	414	418	412	56.60	0.92
Quality grade[c]	687	690	688	1370	0.92

[a]100 = A^{00}; 200 = B^{00}
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$
[c]600 = $Select^{00}$; 700 = $Choice^{00}$
Least-squares means within a row with different letters (a-c) differ ($P < 0.05$)

carcasses with lower fat thickness and lower marbling scores than Hereford × Angus progeny.

Temperament categories did not affect the factors used to determine USDA yield grades (Table 8). However, the carcasses of cattle in the Calm and Intermediate temperament categories had numerically heavier carcasses than those from the Excitable category. Though this difference was not statistically significant, it is of a relatively large magnitude and may warrant further investigation. Temperament category did not affect quality grade factors, particularly marbling score. The quality grades of cattle in all three groups were equivalent to the upper half of the US Select grade. In contrast, Voisinet et al. (1997a) reported that animals with excitable temperaments as determined by a chute score were more likely to exhibit borderline dark cutting lean. In the present study, none of the animals evaluated possessed dark cutting lean characteristics. Additionally, lean maturity, which depends largely on lean color, was similar among temperament categories.

4.4. Tenderness and meat quality characteristics

The initial analysis of variance for pH values indicated that the temperament category by hour postmortem interaction was not a significant source of variation for pH and that the main effect of temperament category tended ($P = 0.15$) to affect pH values. Because the pH decline was of particular interest, the simple effects of temperament category at each postmortem hour were investigated. This analysis indicated that at 0.5 h postmortem, the carcasses from steers classified as Calm had higher ($P < 0.05$) muscle pH values in the *M. longissimus lumborum* than those identified as Excitable or Intermediate (Figure 7). Though the magnitude of this difference (0.2 and 0.1 pH units,

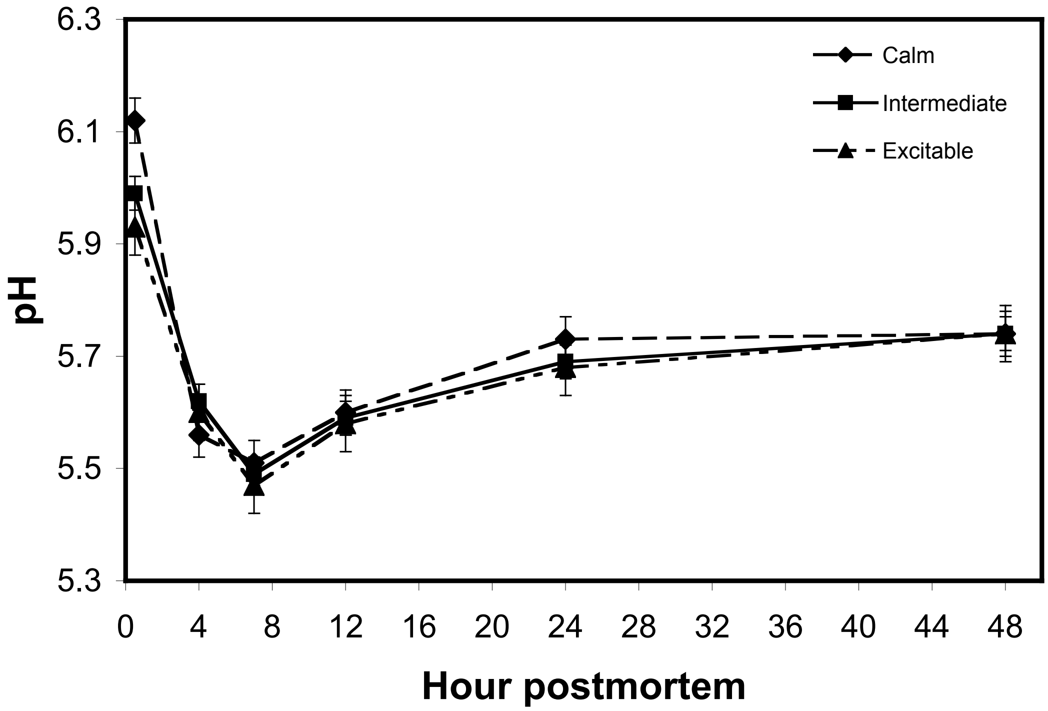

Figure 7. Least-squares means for pH decline the *M. longissimus lumborum* of feedlot steers stratified into temperament categories.

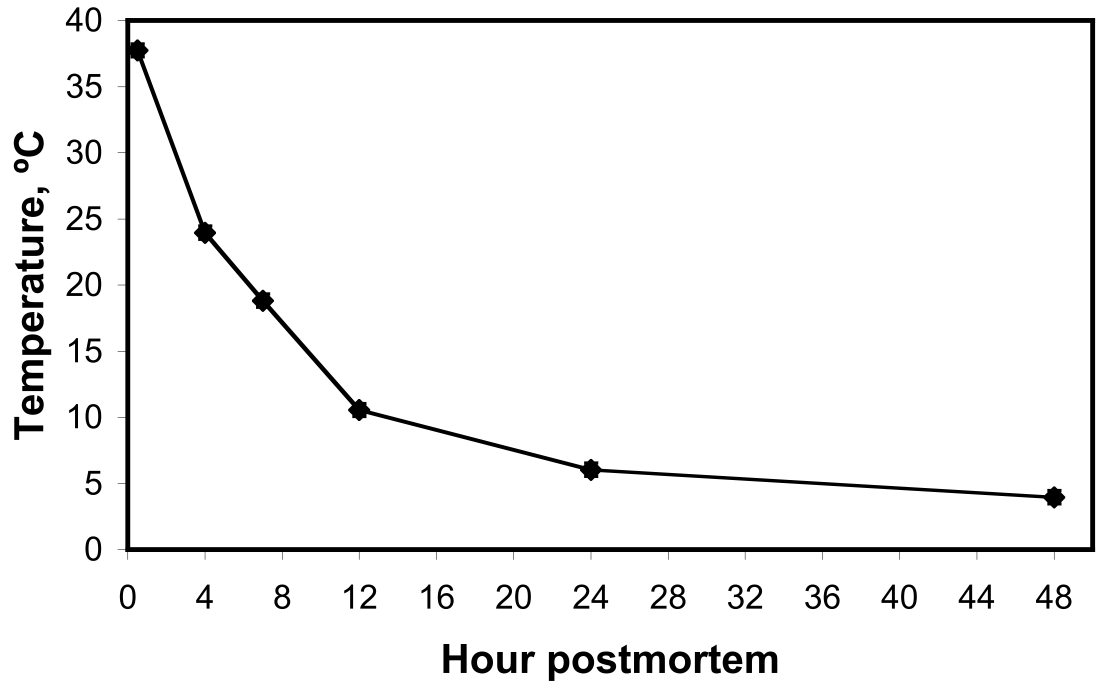

Figure 8. Least-squares means for the temperature decline of the *M. longissimus lumborum* of feedlot steers.

respectively) is relatively small, these differences occurred after high-voltage electrical stimulation, which should have caused postmortem metabolism to occur at its maximum rate. The decline of muscle pH in all of the carcasses was very rapid. At 0.5 h postmortem, the carcasses from Calm cattle had a muscle pH of approximately 6.1, whereas the carcasses of the Intermediate and Excitable cattle had muscle pH values of 6.0 and 5.9, respectively. All carcasses had reached ultimate pH within 4 h postmortem. A minimum pH value was observed at 7 h postmortem, after which muscle pH increased during the next 40 h. Muscle temperature decline did not differ between temperament categories at any time postmortem (Figure 8). The muscle pH was well below 6.0 before the muscle temperature reached 15ºC. Muscle temperature did not reach this level until after 7 to 12 h postmortem. This indicates that conditions were appropriate to prevent cold-induced sarcomere shortening. Marsh and Leet (1966) reported that if muscle pH had dropped below 6.0 before being chilled below 15ºC, sarcomere shortening, and consequently muscle toughening was prevented.

The percentage of ether extractable lipid in the *M. longissimus lumborum* was higher ($P < 0.05$) in the two groups of Angus steers than in the Bonsmara-sired steers (Table 9). This is in agreement the higher marbling scores in the Angus-sired cattle. The greater lipid concentration was associated with lesser ($P < 0.05$) moisture content. CIE L* values were higher ($P < 0.05$) for the muscles from the carcasses produced by the Angus calf-fed steers than for those produced by the yearling-fed Angus steers. The L* values obtained from the carcasses of the Bonsmara-sired steers were lower ($P < 0.05$) than those from either of the other two groups. The CIE a* and b* values generally were higher in the two groups of yearling-fed steers than in the calf-fed steers.

The CIE a* values were highest in the carcasses from the yearling-fed Angus steers and lowest in the carcasses from the calf-fed Angus steers. The a* values obtained from the yearling-fed Bonsmara steer carcasses were intermediate. The CIE b* values were highest in the Bonsmara yearling-fed steer carcasses, lowest in the calf-fed Angus steer carcasses, and intermediate in the yearling-fed Angus carcasses. Calpastatin activity did not differ between the contemporary groups.

Temperament classification did not affect the proximate composition of the muscle, muscle color values, or 72-h calpastatin activity in these carcasses (Table 10). Voisinet et al. (1997a) reported that animals with more excitable temperaments had higher incidence of the dark cutting lean condition. However, the results of the present study indicate that CIE L*, a*, and b* values corroborate the carcass grade data in that none of the animals displayed the dark cutting condition.

Temperament classification and contemporary group interacted to affect sarcomere length (Figure 9). Sarcomere lengths in muscles from the yearling-fed Angus steers classified as having Calm temperaments were longer ($P < 0.05$) than those from all other contemporary group and temperament classifications except the Calm temperament yearling-fed Bonsmara sired steers which were intermediate. It is not clear what biological mechanism may have caused these differences in sarcomere length. Differences in sarcomere length are not generally observed in comparisons of the same muscle from carcasses that were hung and chilled in the same manner.

Table 9
Least-squares means for meat quality traits of feedlot steers fed in three contemporary groups

	Contemporary group				
	Bonsmara yearling-fed	Angus calf-fed	Angus yearling-fed	RMSE	*P* > F
Chemical fat, %	2.50b	4.41a	4.20a	1.39	<0.001
Moisture, %	74.62a	73.07b	73.50b	2.44	0.01
*L**	42.09c	48.10a	44.78b	5.64	<0.001
*a**	31.93ab	30.78b	31.98a	1.24	<0.01
*b**	23.79a	22.45b	23.44ab	1.67	<0.01
Calpastatin activity	0.94	1.02	0.96	0.25	0.84

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

Table 10
Least-squares means for meat quality traits of feedlot steers stratified by temperament categories

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Chemical fat, %	3.78	3.44	3.88	1.39	0.43
Moisture, %	73.35	74.20	73.63	2.44	0.23
*L**	44.75	45.10	45.11	5.64	0.91
*a**	31.89	31.29	31.50	1.24	0.31
*b**	23.62	22.95	23.11	1.67	0.35
Calpastatin activity	1.02	0.97	0.93	0.25	0.91

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

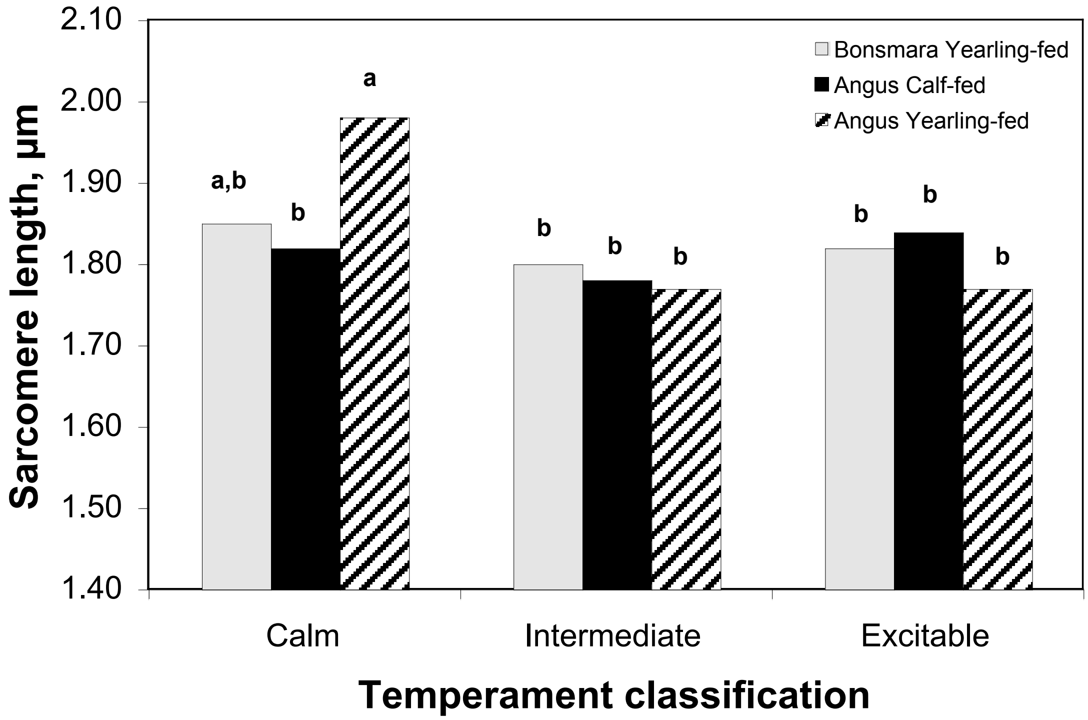

Figure 9. Least-squares means for sarcomere length of feedlot steers fed in three contemporary groups and stratified into temperament categories. (RMSE = 0.01; Interaction $P <$ F = 0.02).

The contemporary group × temperament classification × aging time interaction was a source of variation for the Warner-Bratzler shear force values (Table 11). The yearling-fed Angus steers classified as Excitable produced *M. longissimus lumborum* steaks with higher Warner-Bratzler shear force values at 7 and 21 d postmortem compared to those steers from that contemporary group classified as Calm or Intermediate. Additionally, the values obtained from these carcasses were numerically higher at 3 d postmortem than their Intermediate or Calm counterparts. The tenderness of steaks from the carcasses of the yearling-fed Bonsmara steers did not differ with regard to temperament category, but the Excitable steers from this contemporary group produced steaks with numerically higher Warner-Bratzler shear force values at 3, 14, and 21 d postmortem. The steaks retrieved from the carcasses of the calf-fed Angus steers did not differ in tenderness with regard to temperament category at any time postmortem.

The cause of the differing responses to temperament effects between the contemporary groups is not readily apparent. It is important to note that the Warner-Bratzler shear force values for all of the treatment groups are relatively low and would be considered tender according to the thresholds identified by Shackelford, Morgan, Savell, and Cross (1991). This may be attributable to the tenderization effects of electrical stimulation on these carcasses (Savell, Smith, & Carpenter, 1978; Cross, Smith, Kotula, & Muse, 1979; Savell, Smith, Carpenter, & Parrish, Jr, 1979). Savell, McKeith, and Smith (1981) reported electrical stimulation increased the aging response of beef and that 10 d of postmortem aging was required to equal the tenderization due to electrical stimulation.

Table 11
Least-squares interaction means for the Warner-Bratzler shear force values of *M. longissimus lumborum* steaks from feedlot steers fed in three contemporary groups and stratified by temperament categories after various aging times

Contemporary group	Temperament category	Aging time, d			
		3	7	14	21
Bonsmara Yearling-fed	Calm	3.50abc	2.98defg	2.23i	2.11i
Bonsmara Yearling-fed	Intermediate	3.38bcd	2.88efg	2.40i	2.31i
Bonsmara Yearling-fed	Excitable	3.71abc	2.61efghi	2.52ghi	2.55fghi
Angus Calf-fed	Calm	3.95ab	2.58efghi	2.95defg	2.57efghi
Angus Calf-fed	Intermediate	3.45bc	3.22cde	2.83efgh	2.51hi
Angus Calf-fed	Excitable	3.49bc	3.06cdefg	2.72efghi	2.43hi
Angus Yearling-fed	Calm	3.27bcde	3.05cdefg	2.91efg	2.45hi
Angus Yearling-fed	Intermediate	3.92ab	2.94efg	3.01defg	2.55fghi
Angus Yearling-fed	Excitable	4.28a	3.93ab	3.08cdefg	3.19cdef
RMSE		0.36			
P > F		0.01			

Least-squares means with different letters (a-i) differ ($P < 0.05$).

Perhaps the tenderness differences due to animal temperament would have been larger had these carcasses not been subjected to electrical stimulation. The greater differences in exit velocity observed in the Angus yearling-fed cattle compared to the other two groups (Figure 2) may partially explain the greater tenderness differences in these cattle. Voisinet et al. (1997a) found that excitable feedlot cattle produced *M. longissimus lumborum* steaks with higher Warner-Bratzler shear force values than those with less excitable temperaments. Additionally, Wulf et al. (1997) reported moderate correlations between chute scores and Warner-Bratzler shear force values and sensory panel tenderness values ($r = 0.49$ and -0.44, respectively; $P < 0.05$).

Partial correlation coefficients between temperament traits were generated using a model that accounted for the effect of contemporary group (Table 12). The greatest relationships between temperament traits and Warner-Bratzler shear force were observed after 21 d of aging. At this time, temperament index and all three exit velocity measurements had low to moderate, positive correlations to tenderness. A positive correlation existed between cortisol levels at arrival at the feedlot and 7-d Warner-Bratzler shear force. This was also the sampling time when the animals were experiencing the greatest stress. The only other temperament variable with a significant correlation to tenderness was between mid-point exit velocity and 7-d Warner-Bratzler shear force values. These values were small, but provide evidence that a moderate relationship between these variables and muscle tenderness exist. The correlation coefficients were relatively constant across exit velocity measurements. This is in contrast to the findings of Curley (2004), Vann et al. (2004), and Falkenberg et al.

Table 12
Partial correlation coefficients between temperament traits and Warner-Bratzler shear force of *M. longissimus lumborum* steaks measured after 3, 7, 14, or 21 d of postmortem aging

	Warner-Bratzler shear force			
Trait	3	7	14	21
Temperament index[a]	0.08	0.12	0.01	0.21[b]
Pre-shipment exit velocity	0.12	0.17	-0.03	0.21[b]
Pre-shipment pen score	-0.01	0.06	0.02	0.15
Pre-shipment chute score	0.06	-0.05	0.07	0.14
Pre-shipment cortisol	0.06	0.04	0.15	0.02
Arrival exit velocity	0.13	0.12	0.11	0.22[b]
Arrival cortisol	0.03	0.34[d]	0.10	0.07
70 d exit velocity	0.08	0.22[b]	0.04	0.28[a]
70 d cortisol	-0.13	-0.04	-0.04	-0.08
Final cortisol	-0.11	-0.02	0.07	0.11

[a]Temperament index = (exit velocity + pen score)/2.
[b]$P < 0.10$.
[c]$P < 0.05$.
[d]$P < 0.01$.
[e] $P < 0.001$.

Table 13
Pearson correlation coefficients between selected meat quality traits and Warner-Bratzler shear force values of *M. longissimus lumborum* steaks measured after 3, 7, 14, or 21 d of postmortem aging

	Warner-Bratzler shear force			
Trait	3	7	14	21
$pH_{0.5}$	0.03	0.03	-0.10	-0.10
pH_4	-0.19[b]	-0.11	-0.30[d]	-0.21[b]
pH_7	-0.16[a]	0.00	-0.09	-0.11
pH_{12}	-0.10	-0.17[a]	-0.43[d]	-0.22[b]
pH_{24}	-0.24[b]	-0.06	-0.26[b]	-0.05
pH_{48}	-0.09	-0.04	-0.12	-0.17
*L**	-0.14	0.00	0.07	0.20
*a**	0.01	-0.03	-0.11	0.01
*b**	-0.06	-0.05	-0.16[a]	-0.02
Chemical fat	-0.17[b]	-0.06	0.08	-0.09
Moisture	0.17[b]	0.08	-0.03	0.11
Sarcomere length	-0.17[b]	-0.23[c]	-0.11	-0.02
72-h Calpastatin activity	0.02	0.18[b]	0.24[c]	0.15[a]

[a] $P < 0.10$.
[b] $P < 0.05$.
[c] $P < 0.01$.
[d] $P < 0.001$.

(2005), all of whom reported reduced prediction when exit velocities were taken later in the production system. The higher correlation coefficients between temperament variables and tenderness after longer aging times suggest that the effects of temperament are mediated through reduced postmortem proteolysis. However, no differences were observed in 72-h calpastatin activity across temperament categories. It is not known whether or not differences in calpastatin activity existed before the 72-h measurement.

Of the pH measurements taken during the chilling of these carcasses, the measurement taken at 4 h postmortem was the most highly correlated to Warner-Bratzler shear force (Table 13). Muscle pH at 12 h was moderately correlated to tenderness at 14 d postmortem. It is notable that these correlations are low to moderate and appear to be higher after advanced aging times. Muscle pH measured at 24 h postmortem was correlated to Warner-Bratzler shear force at 3 and 14 d postmortem, but not at 7 or 21 d postmortem.

Ether extractable fat and moisture content was correlated to Warner-Bratzler shear force values at 3 d postmortem, but not after longer aging times. Additionally, sarcomere length was correlated to Warner-Bratzler shear force at 3 and 7 d postmortem, but no correlation was evident at 14 or 21 d postmortem. Conversely, 72-h calpastatin activity was not correlated to tenderness at 3 d postmortem, but this relationship became more evident after increased postmortem storage. The trends in the correlations observed between these meat quality traits and Warner-Bratzler shear force is interesting because it indicates that the primary causes of tenderness change during aging. This idea is substantiated by the wide range in relationships observed between these variables and tenderness in previous studies.

Based on these correlations, sarcomere length, 72-h calpastatin activity, 4-h pH and ether extractable fat were the four variables that were most often related to tenderness after various aging times. The overall relationships of these variables were relatively low, with no one variable explaining a large amount of the variation in tenderness. This lack of predictive power may be due, in part, to the application of electrical stimulation to these carcasses immediately postmortem. Though this technology has been studied extensively, the mechanism for the improvements are still not well understood, though the increased rate of pH decline is clearly involved (Bowling, Smith, Dutson, & Carpenter, 1978). Mechanisms for the response to electrical stimulation that have been suggested included: prevention of cold shortening, increased proteolysis (Bowling et al., 1978), physical disruption of muscle fibers (Savell, Dutson, Smith, & Carpenter, 1978), and the mitigation of cold-induced toughening independent of sarcomere length (King, Voges, Hale, Waldron, Taylor, & Savell, 2004). The extremely low correlation coefficients observed in this study may provide support for the latter theory.

As previously discussed, the temperament ratings were intended to be predictive of the stress responsiveness of the animal. Previous work pertaining to stress effects on muscle tenderness are mixed. Warner-Bratzler shear force values were not affected in lambs stressed by exercise (Bond, Can, & Warner, 2004), nutritional stress, shearing, or washing (Bray, Graafhuis, & Chrystall, 1989). Geesink et al. (2001) found that stressing lambs in a swim wash increased the proportion of muscles with high ultimate pH, which was associated with tougher meat, but then failed to find an effect of the washing treatment on tenderness independent of pH. Apple et al. (1995) reported that restraint and isolation stress increased plasma glucocorticoid and catecholamine concentrations and subsequently increased postmortem pH and reduced Warner-Bratzler shear force values in the lamb muscles. In contrast, Jeremiah et al. (1988) subjected bulls and steers to a minimal or normal stress treatment during transport and lairage before slaughter. Those authors found that steers exposed to the minimal stress treatment produced steaks that received higher initial and overall tenderness ratings than steers exposed to the normal stress treatment or bulls subjected to either treatment.

A possible source of the discrepancies observed in the findings of studies relating stress responses to tenderness may be the immediate versus the long-term effects of stress responsiveness. In the short term, both catecholamines and glucocorticoids produce a net catabolic effect on muscle tissue (Exton, 1987). When an acute stressor is applied immediately antemortem, proteolytic degradation is initiated in the muscle tissue and is likely continued postmortem, which would improve tenderness. Under chronic stress response conditions, as in the case of the excitable group, animals may be less susceptible to this effect. Additionally, stress conditions may cause a state of mild metabolic acidosis (Schaefer et al., 1997; Parker et al., 2003). Schaefer et al. (1988) subjected cattle to minimal transport with 24 h feed withdrawal, 320 km transport plus 48 h feed withdrawal, or two 320 km transport sessions plus 72 h feed withdrawal. Those authors saw shifts in blood acid-base balance in all treatment groups compared to the pretreatment samples, but the shift appeared to be greatest in the animals transported 320 km plus 48 h feed withdrawal. Those authors suggested that the animals transported 320 km twice plus 72 h feed withdrawal may have begun to recover during the longer lairage times. A companion paper evaluated the tenderness of the meat from these animals (Jones et al., 1988) and reported that steaks produced from cattle that had been transported and held without feed for 72 h before slaughter were less tender than those produced from non-transported cattle, or those that had been transported and held without feed for 48 h. These shifts in acid-base balance may mediate the negative effects on muscle tenderness. Oxidative conditions and increased ionic strength early postmortem have been reported to decrease μ-calpain activity, reduce proteolysis of cytoskeletal proteins, and thereby reduce the tenderization of beef (Rowe, Maddock, Lonergan, & Huff-Lonergan, 2004a,b). This might explain the observation that the relationship between Warner-Bratzler shear force and temperament were greatest after longer aging times. The longer postmortem storage would have provided a greater opportunity for differences in proteolysis to appear.

The primary difference between the two groups of Angus cattle was that the yearling-fed steers were fed for 113 d, whereas the calf-fed steers were fed for 202 d. These two groups of steers were from a common herd, were similar in genetics, and received similar management prior to weaning. Therefore, the primary difference between these contemporary groups was time on feed. Previous research has repeatedly indicated that extended feeding periods improves tenderness. Aberle, Reeves, Judge, Hunsley, and Perry (1981) reported that increased duration of feeding improved tenderness. Perhaps improvement in tenderness associated with increased days on feed may be due, in part, to the reduction or elimination of the impact temperament has on tenderness. Lunt and Orme (1987) indicated that calf-fed heifers produced beef that received higher sensory panel tenderness ratings than yearling-fed heifers after 7 d of postmortem storage. In contrast, Harris et al. (1997) reported no difference in the palatability traits of beef from calf-fed and yearling-fed animals when fed to either constant age or body weight end-points.

CHAPTER V

USING SINGLE TEMPERAMENT MEASURES FOR SORTING CATTLE INTO OUTCOME GROUPS

The primary interest in investigating relationships between temperament and meat quality is the potential for identifying and managing cattle to the appropriate marketing endpoint in a more effective manner. These animals could be sorted and managed to optimize production efficiencies, and information could be used in breeding decisions.

Practical application of such information would require the consideration of several factors. The first is that decisions must be made early in the production system to provide effective management. Additionally, collecting the appropriate data should not impede the operation of the facility. Often, reliable information about the animals and their management history is not available so multiple evaluations may not be feasible. In the present study, the effectiveness of temperament measures taken at each point of production were evaluated in their capacity to sort animals in to outcome groups. Because the analyses presented in the previous chapter indicated significant differences in the response of the calf-fed and yearling-fed animals to temperament, separate analyses were conducted on the animals from each group.

5.1. Results of sorting yearling-fed steers

The yearling-fed cattle consisted of steers from two sources: The Bonsmara-sired steers and Angus-sired steers. The time on feed was 132 and 113 d, respectively. Within each group, cattle were segmented into temperament categories based on exit velocity and pen scores taken before transport to the feedlot.

Table 14
Least-squares means for temperament indicating traits of yearling-fed steers stratified by temperament categories before shipment to the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	$P > F$
N	15	50	16		
Pre-shipment temperament index[a]	1.75c	2.98b	4.20a	0.31	<0.001
Pre-shipment exit velocity, m/s	1.45c	2.67b	3.47a	0.37	<0.001
Pre-shipment pen score	1.07c	2.56b	3.47a	0.65	<0.001
Pre-shipment chute score	0.68c	1.12b	1.50a	0.50	0.01
Pre-shipment cortisol, ng/mL	11.92b	12.02b	16.13a	26.86	0.02
Arrival exit velocity	1.30c	2.05b	2.89a	0.74	<0.001
Arrival cortisol, ng/mL	10.48	12.46	13.20	52.64	0.55
Mid-point exit velocity	1.23c	1.86b	2.75a	0.64	<0.001
Mid-point cortisol, ng/mL	8.82	12.10	13.50	37.34	0.09
Final cortisol, ng/mL	9.85	10.90	11.69	32.96	0.67

[a]Temperament index = (exit velocity + pen score)/2.
Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

Due to classification method, all temperament-indicating variables differed ($P < 0.05$) across temperament categories (Table 14). Differences were maintained in subsequent exit velocity measurements, although the magnitude of the differences diminished as the animals grew larger. This is likely due to a combination of the larger cattle having more difficulty moving through the facility and habituation with increasing experience to being handled.

Serum cortisol concentrations were higher ($P < 0.05$) in the Excitable cattle than the other groups at the pre-shipment sampling. No differences in cortisol concentrations were observed between the groups when the cattle arrived at the feeding facility, though Excitable cattle had numerically higher cortisol concentrations at this sampling time. This may be partly due to the stress associated with transport affecting circulating glucocorticoids in all of the cattle. At 70 d on feed, serum cortisol concentrations tended ($P = 0.09$) to increase with increasing excitability. No differences in cortisol concentrations were apparent among temperament categories immediately before slaughter.

The pH decline was extremely rapid in the carcasses in this study (data not shown). At the initial measurement taken at 0.5 h postmortem, Calm and Intermediate carcasses had mean pH values of 5.95 and 5.98, respectively in the *M. longissimus lumborum,* while the pH of the Excitable carcasses was 5.85. This difference was small. However, these carcasses had been subjected to high voltage electrical stimulation, which largely depleted muscle glycogen stores as evidenced by the low pH values early postmortem. The carcasses of the Excitable steers had a slightly lower muscle pH of 5.85 at this time. *M. longissimus lumborum* pH reached a minimum value (5.5) by 7 h postmortem. During the next 40 h, the pH increased to approximately 5.7. Muscle temperature did not differ between temperament categories at any time postmortem (data not shown). Muscle temperature was 36°C at 0.5 h postmortem and decreased to 17.8 and 4.4°C by 7 and 48 h postmortem, respectively.

Carcass yield or quality grade characteristics did not differ between temperament categories (Table 15). However, hot carcass weights and adjusted fat thickness were numerically greater for the cattle with calmer temperaments. Perhaps, Calm animals possessed a slight advantage in growth and fattening ability due to their calmer temperament. The mean marbling scores for cattle in this trial were equivalent to US Select.

No differences due to temperament category were observed in proximate composition, muscle color, sarcomere length, or 72-h calpastatin activity (Table 16). Additionally, the temperament category × aging interaction was not significant for Warner-Bratzler shear force in this trial. However, aging resulted in considerable improvements in tenderness (data not shown). When values were pooled across aging times, steaks from cattle in the Excitable group produced higher ($P < 0.05$) Warner-Bratzler shear force values than the Calm or Intermediate groups (Table 16). Analysis of the simple effects of temperament within aging time indicated that Warner-Bratzler shear force values were 0.5 and 0.6 kg higher ($P < 0.05$; Figure 10) at 7 d postmortem in steaks produced by the Excitable cattle than those from the Intermediate and Calm cattle, respectively. Additionally, steaks from the Excitable cattle tended to be tougher at 3 and 21 d postmortem. The mechanism responsible for this tenderness difference is

Table 15
Least-squares means for carcass traits of yearling-fed steers stratified by temperament categories before shipment to the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Hot carcass weight, kg	364	354	352	1053	0.52
Adjusted fat thickness, cm	1.66	1.54	1.45	0.11	0.21
Longissimus muscle area, cm^2	94.48	95.28	93.86	80.58	0.85
Estimated kidney, pelvic, and heart fat, %	1.91	1.92	1.86	0.23	0.91
USDA yield grade	3.04	2.81	2.76	0.37	0.37
Overall maturity[a]	164	163	164	0.37	0.97
Marbling score[b]	419	404	417	4298	0.66
USDA quality grade[c]	691	682	688	1064	0.55

[a]100 = A^{00}; 200 = B^{00}.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$.
[c]600 = $Select^{00}$; 700 = $Choice^{00}$.

Table 16
Least-squares means for meat quality traits of yearling-fed steers stratified by temperament categories before shipment to the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Chemical fat, %	3.98	3.41	3.50	1.30	0.21
Moisture, %	73.73	74.12	74.80	2.30	0.14
*L**	42.49	43.23	43.74	6.13	0.38
*a**	31.81	31.75	31.74	1.24	0.98
*b**	23.30	23.48	23.24	1.99	0.81
Sarcomere length, µm	1.86	1.84	1.82	0.001	0.37
72- h calpastatin activity	1.01	0.99	0.94	0.25	0.92
Warner-Bratzler shear force, kg	2.88b	2.97b	3.34a	0.53	0.01

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

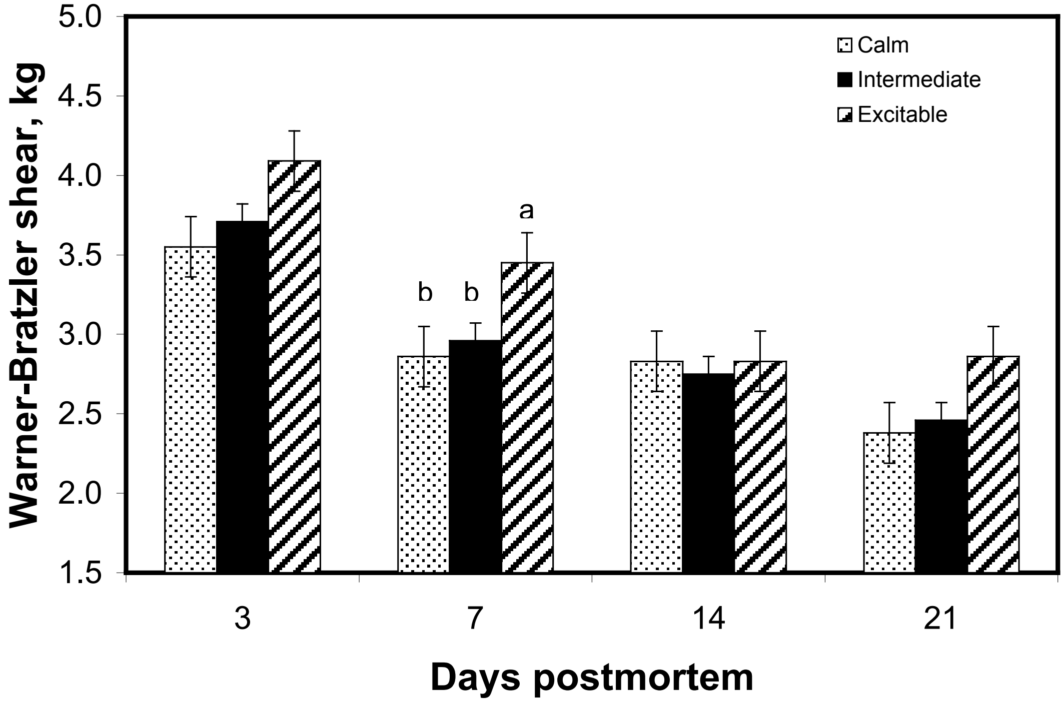

Figure 10. Least-squares means for the simple effects of temperament category within aging time on Warner-Bratzler shear force values of *M. longissimus lumborum* steaks from yearling-fed feedlot steers stratified by temperament categories before shipment to the feeding facility.

not readily apparent because none of the meat quality traits measured in this study were affected by temperament category.

The same steers were sorted into temperament categories based on exit velocity when they arrived at the feedlot. Because the feedlots' facilities were not conducive to the collection of pen scores and chute scores, these data were not collected on arrival or during subsequent evaluations. Because pen scores were not available, the cattle were sorted into temperament categories based solely on exit velocity. The least-squares means for the temperament data for these groupings are presented in Table 17.

Several animals were redistributed among the temperament categories compared to the pre-shipment classifications. Therefore, the differences in arrival exit velocity are larger in magnitude between the groupings assigned on arrival in comparison to the groupings assigned before transport. Serum cortisol levels differed ($P < 0.05$) between these groups on arrival, but not at later samplings. Increasing excitability was consistently associated with numerically higher cortisol concentrations at all samplings.

The decline in *M. longissimus lumborum* muscle pH did not differ between temperament categories determined on arrival at the feeding facility (data not shown). The declines mirrored those observed when the cattle were sorted at the pre-shipment evaluation. However, the cattle in the Excitable group had pH values that were slightly lower (0.1 unit ($P < 0.05$) on a numerical basis than the other two groups at the 0.5 h measurement. Additionally, muscle temperature did not differ between temperament categories at any time measured (data not shown).

Table 17
Least-squares means for temperament traits of yearling-fed steers stratified by temperament categories on arrival at the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
N	14	58	9		
Arrival exit velocity	1.04c	2.1b	4.15a	0.32	<0.001
Arrival cortisol, ng/mL	9.29b	12.12b	17.59a	48.55	0.02
Mid-point exit velocity	1.27c	1.9b	3.09a	0.65	<0.001
Mid-point cortisol, ng/mL	10.65	11.86	12.73	39.42	0.73
Final cortisol, ng/mL	8.28	11.08	13.46	31.29	0.09

Least-squares means within a row with different letters (a-c) differ (*P* < 0.05).

The least-squares means for the carcass characteristics and USDA grade factors for the temperament classifications made upon arrival at the feed lot are presented in Table 18. As noted earlier, animal temperament did not alter carcass characteristics. Calmer cattle produced carcasses that were numerically heavier than those that exhibited excitable temperaments. Adjusted fat thickness also was numerically lower in the Excitable cattle.

None of the physical and chemical traits measured were affected by temperament classifications assigned at this time (Table 19). Warner-Bratzler shear force tended (P = 0.14) to be affected by the arrival temperament category main effect. In contrast to the results observed for the pre-shipment classifications, the steaks from Calm and Intermediate groups had numerically higher ($P < 0.05$) Warner-Bratzler shear force values than those observed in the steaks from Excitable cattle. Examination of the simple effects of temperament classification at each aging time (Figure 11) indicated that at d-3 postmortem, the Excitable group produced steaks that were less tender ($P < 0.05$) than those produced by the Calm or Intermediate steers. This effect did not approach statistical significance after the longer aging times, but the same numerical trend was observed after these aging times.

Table 18
Least-squares means for carcass traits of yearling-fed steers stratified by temperament categories on arrival at the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Hot carcass weight, kg	404	393	384	1010	0.33
Adjusted fat thickness, cm	1.52	1.53	1.46	0.12	0.88
Longissimus muscle area, cm^2	95.41	94.48	94.69	78.61	0.94
Estimated kidney, pelvic, and heart fat, %	1.74	1.93	1.94	0.21	0.40
USDA yield grade	2.99	2.98	2.84	0.36	0.81
Lean maturity	163	158	159	139	0.47
Skeletal maturity	166	162	170	183	0.19
Overall maturity[a]	166	162	166	81	0.25
Marbling score[b]	387	414	413	4240	0.39
USDA quality grade[c]	673	687	686	1054	0.37

[a]100 = A^{00}; 200 = B^{00}.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$.
[c]600 = $Select^{00}$; 700 = $Choice^{00}$.

Table 19
Least-squares means for meat quality traits of yearling-fed steers stratified by temperament categories on arrival at the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Chemical fat, %	3.38	3.56	3.35	1.34	0.80
Moisture, %	74.12	74.15	74.44	2.41	0.86
*L**	42.51	43.49	42.43	6.07	0.26
*a**	31.82	31.81	32.02	1.23	0.72
*b**	23.41	23.36	23.62	2.00	0.88
Sarcomere length, µm	1.84	1.84	1.85	0.01	0.82
72-h Calpastatin activity	0.96	0.98	1.00	0.25	0.98
Warner-Bratzler shear force, kg	2.97	2.93	2.36	0.53	0.14

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

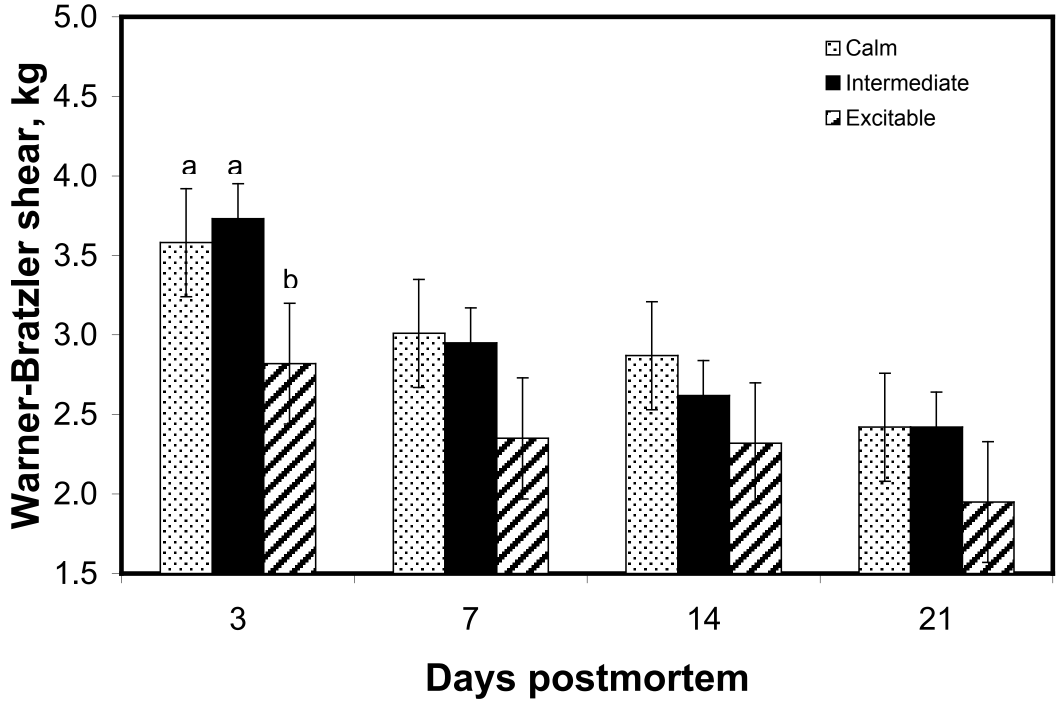

Figure 11. Least-squares means for the simple effects of temperament category within aging time on Warner-Bratzler shear force values of *M. longissimus lumborum* steaks from yearling-fed feedlot steers segmented into temperament categories on arrival at the feeding facility.

The final temperament classification was made after approximately 70 d on feed. The least-squares means for the temperament indicating traits for the cattle sorted at 70 d on feed are presented in Table 20. These classifications were based on exit velocities in the same manner as the arrival temperament classifications. Serum cortisol concentrations at this sampling were consistent with the mid-point groupings. Immediately before being transported to the packing plant, cattle determined to be Excitable at the mid point sampling had higher ($P < 0.05$) circulating cortisol concentrations than those determined to have Calm or Intermediate temperaments.

The muscle pH and temperature decline curves in the *M. longissimus lumborum* for the temperament categories determined at 70 d on feed did not differ with respect to temperament category at any time postmortem (data not shown). At 0.5 h postmortem, muscle pH was below 6.0 in all carcasses and had dropped to a minimum of 5.5 by 7 h. During the next 40 h, the muscle pH increased to 5.7. However, at 0.5 h postmortem, the carcasses in the Intermediate group appeared to have numerically higher pH values in the *M. longissimus lumborum*.

In partial agreement with our earlier observations on sorting these cattle using temperament indicators, the midpoint temperament category tended to affect adjusted fat thickness ($P = 0.10$) and USDA yield grade in these cattle (Table 21). The cattle from the Excitable group had numerically lower adjusted fat thicknesses, as well as numerically lower yield grades. These data may suggest that the Excitable cattle were more difficult to finish than their calmer pen mates.

Table 20
Least-squares means for temperament traits of yearling-fed steers stratified by temperament categories after approximately 70 d on feed

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
N	10	59	12		
Mid-point exit velocity, m/s	0.89c	1.74b	3.66a	0.25	<0.001
Mid-point cortisol, ng/mL	9.87	11.36	15.22	37.27	0.09
Final cortisol, ng/mL	12.23b	9.47b	16.55a	26.61	<0.01

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

Table 21
Least-squares means for carcass traits of yearling-fed steers stratified by temperament categories after approximately 70 d on feed

Trait	Temperament category: Calm	Intermediate	Excitable	RMSE	$P > F$
Hot carcass weight, kg	386	398	382	999	0.22
Adjusted fat thickness, cm	1.49	1.56	1.33	0.11	0.10
Longissimus muscle area, cm^2	94.73	94.67	94.62	78.74	0.99
Estimated kidney, pelvic, and heart fat, %	1.94	1.89	1.90	0.22	0.95
USDA yield grade	2.89	3.03	2.68	0.35	0.16
Lean maturity	159	159	162	140	0.69
Skeletal maturity	165	164	163	190	0.91
Overall maturity[a]	163	163	163	84	0.99
Marbling score[b]	392	415	397	4262	0.48
USDA quality grade[c]	682	686	680	1075	0.81

[a]100 = A^{00}; 200 = B^{00}.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$.
[c]600 = $Select^{00}$; 700 = $Choice^{00}$.

Table 22
Least-squares means for meat quality traits of yearling-fed steers stratified by temperament categories after approximately 70 d on feed

Trait	Temperament category: Calm	Intermediate	Excitable	RMSE	$P > F$
Chemical fat, %	3.64	3.54	3.19	1.33	0.59
Moisture	74.46	74.13	74.22	2.41	0.82
$L*$	43.52	43.35	42.12	6.07	0.27
$a*$	31.77	31.70	32.07	1.22	0.58
$b*$	23.43	23.34	23.69	1.98	0.73
Sarcomere length, µm	1.84	1.84	1.84	0.01	0.99
72-h Calpastatin activity	0.89	1.00	0.99	0.25	0.81
Warner-Bratzler shear force, kg	3.06	3.18	2.56	0.53	0.10

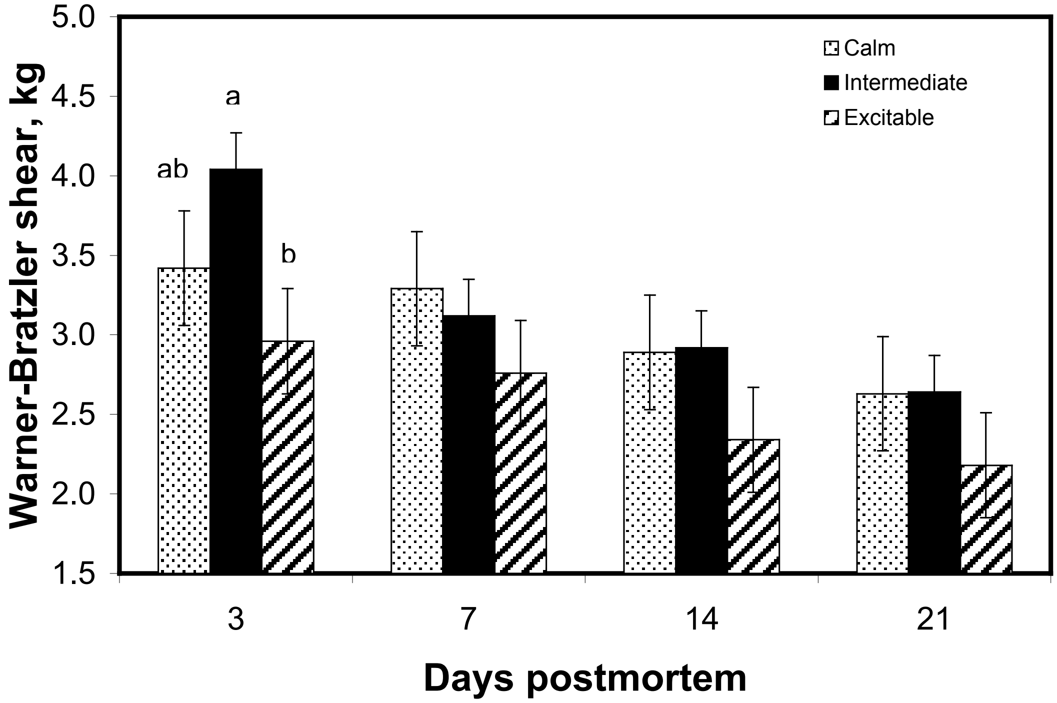

Figure 12. Least-squares means for the simple effects of temperament category within aging time on Warner-Bratzler shear force values of *M. longissimus lumborum* steaks from yearling-fed feedlot steers segmented into temperament categories after approximately 70 d on feed.

In agreement with the findings regarding earlier sorting times, none of the chemical and physical traits measured differed between temperament categories (Table 22). In contrast to the temperament categories made before shipment to the feeding facility, cattle classified as Excitable in the middle portion of the feeding period tended ($P = 0.10$) to have lower Warner-Bratzler shear force values than those with less excitable dispositions. However, this is consistent with the observations made when the cattle arrived at the feeding facility. The simple effects of temperament on Warner-Bratzler shear forced within each aging time indicated that after 3 d of postmortem, refrigerated storage, the steaks produced from the carcasses of the Intermediate steers were less tender ($P < 0.05$) than those obtained from the carcasses of steers classified as Excitable at the midpoint sampling (approximately 70 d on feed; Figure 12). The steaks produced from the carcasses of the Calm steers were intermediate in tenderness after 3 d of postmortem aging. After 7, 14, or 21 d of postmortem aging, this effect no longer approached statistical significance. Though the steaks from the Excitable steers had numerically lower Warner-Bratzler shear force values at each of these aging times, the magnitude of the differences was smaller. It appeared that the relationship of temperament to muscle tenderness changed as the feeding period progressed. It also appeared that sorting cattle before shipment to the feeding facility identified yearling steers that were more likely to produce beef that was less tender than their calmer pen mates. However, at later evaluations, the opposite appeared to be true.

5.2. Results of sorting calf-fed steers

The calf-fed cattle were Angus-sired steers that had been backgrounded for 40 d after weaning before being placed on feed. This allowed them to recover from the stress of weaning before being transported to the feed yard. These steers were fed for 202 d before being slaughtered. These cattle were sorted at three times during the feeding period on temperament indicating measurements in the same manner used for the yearling-fed steers. The initial sorting was conducted on the farm before the cattle were shipped to the feedlot. Temperament traits documented at this time included exit velocity, pen score, and chute score. Exit velocity and pen score were combined to create a temperament index as described for the yearling-fed trial. This index value was used to segment these steers into Calm, Intermediate, or Excitable temperament classifications.

The temperament measurements were consistent with one another and the differences between temperament categories were maintained throughout the feeding period (Table 23). However, the magnitude of the differences between groups decreased over time. This trend is consistent with our observations in the yearling-fed trial, but is even more pronounced. Interestingly, none of the serum cortisol concentrations measured differed between pre-shipment temperament categories. However, midpoint cortisol concentrations tended (P = 0.13) to be higher in the Excitable cattle. Numerically, however, higher cortisol concentrations were associated with greater excitability. Chute score did not to differ between temperament categories, even though these values tended (P = 0.08) to be affected by temperament category and numerically ranked the categories accordingly.

Table 23
Least-squares means for temperament indicating traits of calf-fed steers stratified by temperament categories before shipment to the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
N	7	33	9		
Pre-shipment temperament index[a]	1.33c	2.48b	4.02a	0.22	<0.001
Pre-shipment exit velocity, m/s	1.23c	2.49b	4.15a	0.42	<0.001
Pre-shipment pen score	1.43c	2.48b	3.89a	0.67	<0.001
Pre-shipment chute score	1.57	1.54	2.22	0.64	0.08
Pre-shipment cortisol, ng/mL	7.24	9.77	10.57	20.18	0.31
Arrival exit velocity, m/s	2.10b	2.54b	3.13a	0.62	0.04
Arrival cortisol, ng/mL	9.75	10.95	13.94	39.25	0.35
Mid-point exit velocity, m/s	2.31	2.44	2.87	0.41	0.15
Mid-point cortisol, ng/mL	13.31	15.17	19.25	37.32	0.13
Final cortisol, ng/mL	15.68	16.10	18.31	45.47	0.65

[a]Temperament index = (exit velocity + pen score)/2.
Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

Carcasses resulting from the steers in this trial had a rapid postmortem pH decline in the *M. longissimus lumborum* (data not shown). Values for *M. longissimus lumborum* pH in the carcasses of the Intermediate and Excitable steers were approximately 6.1 with the carcasses of the calm cattle having pH values of 6.2 at 0.5 h postmortem. Muscle pH of the *M. longissimus lumborum* did not differ between temperament categories at any time postmortem. However carcasses from the Excitable group tended to have slightly lower muscle pH values at 4 h postmortem (5.65 versus 5.71 and 5.75, respectively). After 12 h postmortem, pH values were approximately 5.5 for all groups. Due to equipment failure, muscle pH was not available after the first 12 h postmortem. Therefore, it is not known if these carcasses exhibited the buffering phenomenon observed in the yearling-fed cattle. Temperament category did not affect the decline in muscle temperature (data not shown).

Carcass traits for the pre-shipment temperament categories are presented in Table 24. None of the carcass traits measured were affected by temperament classification. The mean quality grades for the carcasses in the trial are equivalent to US Choice and Select. The cattle classified as Calm produced carcasses that were numerically heavier with slightly more adjusted fat thickness.

Similarly, temperament category had no effect on proximate composition, muscle color, sarcomere length, or 72-h calpastatin activity (Table 25). The temperament category × aging interaction was not a source of variation in Warner-Bratzler shear force at any of the classification times in this trial. However, aging consistently improved the tenderness of the *M. longissimus lumborum* steaks in this trial (data not shown).

Table 24
Least-squares means for carcass traits of calf-fed steers stratified by temperament categories before shipment to the feeding facility

Trait	Temperament category: Calm	Intermediate	Excitable	RMSE	*P* >F
N	7	33	9		
Hot carcass weight, kg	353	347	347	1719	0.93
Adjusted fat thickness, cm	1.86	1.72	1.75	0.12	0.64
Longissimus muscle area, cm^2	84.69	81.78	83.25	84.95	0.72
Estimated kidney, pelvic, and heart fat, %	2.22	2.18	2.17	0.16	0.97
USDA yield grade	3.53	3.47	3.43	0.37	0.95
Overall maturity[a]	163	163	159	35.6	0.35
Marbling score[b]	412	437	416	6076	0.28
USDA quality grade[c]	681	704	691	1324	0.26

[a]100 = A^{00}; 200 = B^{00}.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$.
[c]600 = $Select^{00}$; 700 = $Choice^{00}$.

Table 25
Least-squares means for meat quality traits of calf-fed steers stratified by temperament categories before shipment to the feeding facility

Trait	Temperament category: Calm	Intermediate	Excitable	RMSE	*P* > F
Chemical fat, %	4.11	4.27	3.87	1.76	0.72
Moisture, %	73.21	73.15	73.85	1.69	0.36
*L**	48.04	48.75	47.34	5.55	0.27
*a**	31.25	30.38	31.07	1.65	0.15
*b**	22.87	22.18	22.68	2.30	0.44
Sarcomere length, µm	1.79	1.79	1.77	0.003	0.65
72–h Calpastatin activity	0.86	1.15	0.97	0.32	0.41
Warner-Bratzler shear force, kg	2.91	3.04	2.86	0.31	0.62

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

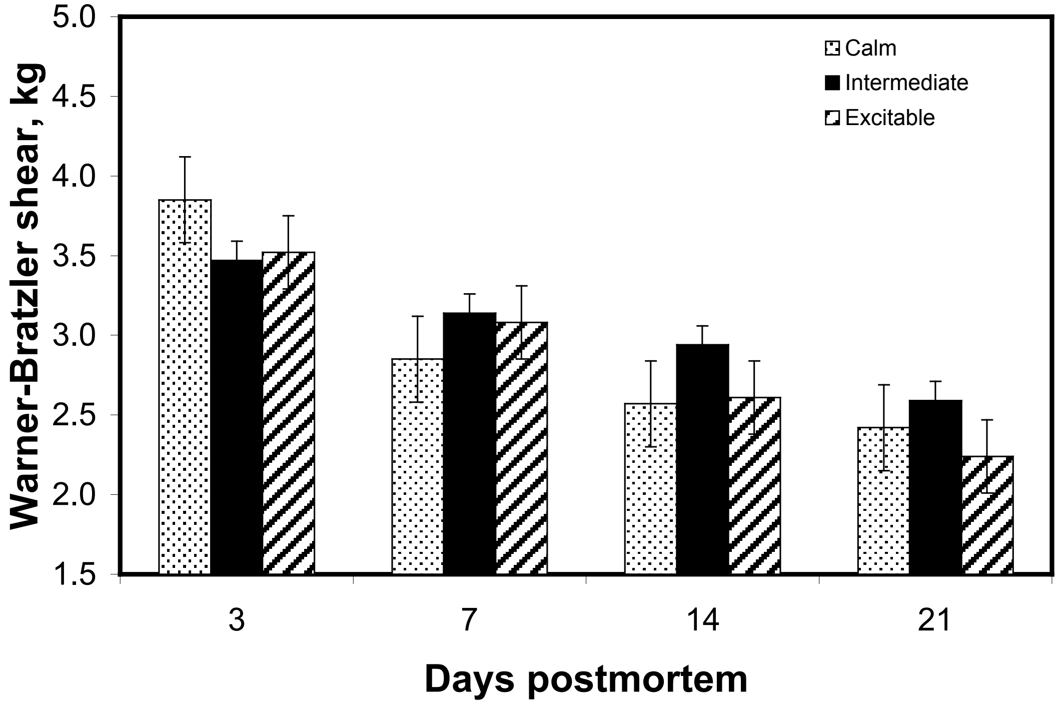

Figure 13. Least-squares means for the simple effects of temperament category within aging time on Warner-Bratzler shear force values of *M. longissimus lumborum* steaks from calf-fed feedlot steers segmented into temperament categories before shipment to the feeding facility.

This trend can be seen in Figure 13, which presents the least-squares means for the simple effects of temperament within each aging time. In agreement with the temperament category main effect, these groups were similar with regard to Warner-Bratzler shear force at all postmortem aging times measured. This lack of tenderness differences between the three temperament categories is in disagreement with the results of the yearling fed trial. It is not clear why the effects of temperament would be different between these two sets of cattle.

Immediately after these steers arrived at the feeding facility, they were processed into the feed yard according to the standard practices of the facility. In addition to the procedures performed by the feed yard staff, serum samples were collected to determine circulating concentrations of glucocorticoids and exit velocity was measured as the animals left the working chute. These exit velocity measures were used to segment the steers into the arrival temperament categories. As noted in the yearling-fed steers, visual inspection of the data indicated that several animals were assigned to different temperament categories relative to their pre-shipment classification. The least-squares means for the temperament traits of the calf-fed steers sorted upon arrival at the feedlot are presented in Table 26. The differences between the temperament categories are consistent with those observed between the pre-shipment temperament classifications. As noted in regard to the pre-shipment classification, serum cortisol levels did not differ between temperament categories at any of the sampling times. It is not completely surprising that these groups did not differ in glucocorticoid concentration on arrival at the feedlot. This is because these animals were transported a great distance between the

Table 26
Least-squares means for temperament traits of calf-fed steers stratified by temperament categories on arrival at the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
N	4	39	5		
Arrival exit velocity	1.18c	2.51b	4.12a	0.28	<0.001
Arrival cortisol, ng/mL	9.77	11.28	13.15	40.54	0.72
Mid-point exit velocity	1.59b	2.57a	2.42a	0.37	0.01
Mid-point cortisol, ng/mL	14.76	15.66	16.45	40.79	0.93
Final cortisol, ng/mL	14.90	16.46	17.66	45.96	0.83

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

Table 27
Least-squares means for carcass traits of calf-fed steers stratified by temperament categories on arrival at the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* >F
Hot carcass weight, kg	348	348	356	1634	0.92
Adjusted fat thickness, cm	1.75	1.74	1.93	0.12	0.51
Longissimus muscle area, cm^2	80.72	83.08	81.16	87.74	0.83
Estimated kidney, pelvic, and heart fat, %	2.25	2.17	2.3	0.16	0.74
USDA yield grade	3.58	3.43	3.81	0.35	0.39
Lean maturity	157	160	154	122	0.53
Skeletal maturity	165	164	160	90	0.61
Overall maturity[a]	163	163	157	34	0.13
Marbling score[b]	392	430	458	8097	0.56
USDA quality grade[c]	684	697	715	1907	0.55

[a]100 = A^{00}; 200 = B^{00}.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$.
[c]600 = $Select^{00}$; 700 = $Choice^{00}$.

farm and the feeding facility. Given the stressful nature of transport, it is likely that all of the animals would have experienced an activated stress response. Furthermore, these animals would have been at various points in the stress response curve and subsequent return to baseline cortisol levels, which complicates the interpretation of these values.

The pH and temperature decline curves of the *M. longissimus lumborum* muscles from the carcasses in this trial were consistent with the curves observed with the pre-shipment classifications. In agreement with our earlier findings, neither pH nor temperature decline were affected by temperament category in this trial. However, at 0.5 h postmortem, the carcasses from Calm steers had numerically higher pH values and the carcasses of the Intermediate steers had numerically the lowest pH values in the *M. longissimus lumborum*.

Carcass characteristics and USDA carcass grade factors were unaffected by temperament categories assigned to the calf-fed steers on arrival to the feed yard (Table 27). This is also consistent with the observations relative to the pre-shipment categories. The Excitable steers had numerically greater adjusted fat thickness compared to their calmer pen mates. Additionally, the carcasses produced by steers identified as having Calm temperaments on arrival at the feedlot had numerically lower marbling scores and subsequent quality grades compared to the cattle identified as Intermediate or Excitable.

Least-squares means for meat quality traits for the steers in this trial segmented by temperament classifications made on arrival at the feed yard are presented in Table 28. Ether extractable lipid content was numerically lower in the steaks from steers classified as Calm, which coincides with the numerical differences in marbling score noted earlier. Calpastatin activity measured at 72-h postmortem tended ($P = 0.12$) to be

Table 28
Least-squares means for meat quality traits of calf-fed steers stratified by temperament categories on arrival at the feeding facility

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Chemical fat, %	3.94	4.10	4.92	1.71	0.40
Moisture, %	72.82	73.41	72.74	1.71	0.43
*L**	49.00	48.17	49.53	5.67	0.42
*a**	29.97	30.65	31.09	1.72	0.45
*b**	21.60	22.38	22.97	2.29	0.41
Sarcomere length, µm	1.78	1.78	1.78	0.01	0.95
72-h Calpastatin activity	1.49	1.08	0.70	0.31	0.12
Warner-Bratzler shear force, kg	3.00	2.97	2.92	0.31	0.97

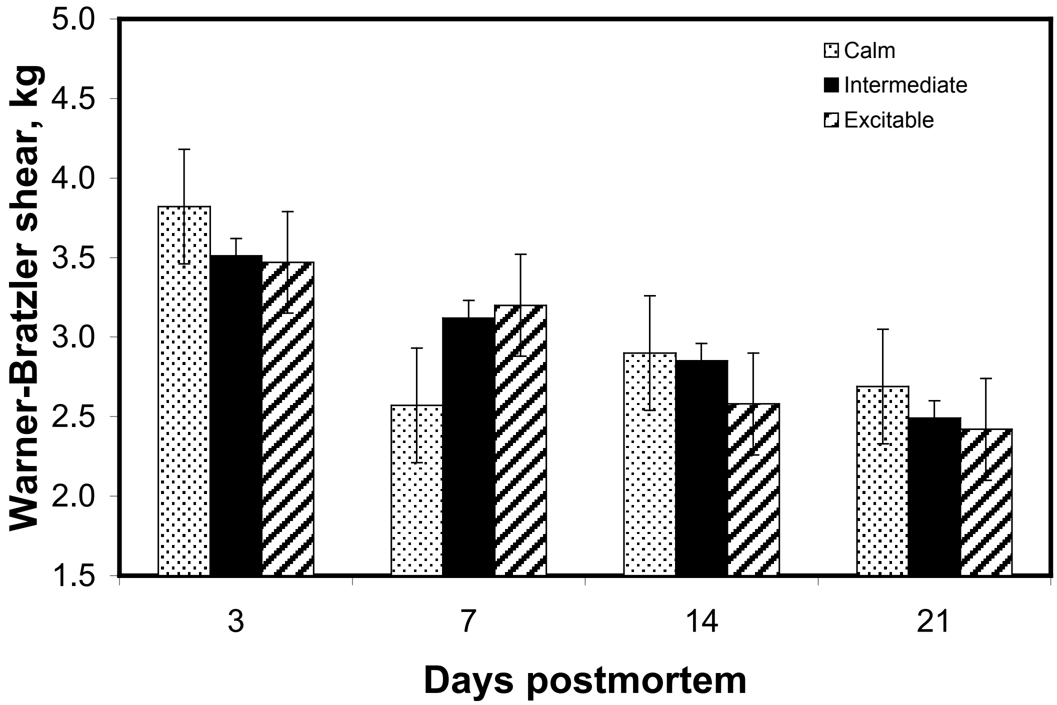

Figure 14. Least-squares means for the simple effects of temperament category within aging time on Warner-Bratzler shear force values of *M. longissimus lumborum* steaks from calf-fed feedlot steers segmented into temperament categories on arrival at the feeding facility.

lower in muscles from Excitable cattle than in the muscles from calmer animals. No other differences were observed in the meat quality traits measured.

Despite the observed trend in calpastatin activity, no differences in Warner-Bratzler shear force due to the temperament category main effect. The simple effects of temperament category within each individual aging time are presented in Figure 14. Temperament did not affect Warner-Bratzler shear force values at anytime postmortem in these animals regardless of postmortem aging time.

The final sorting of the calf-fed cattle was based on exit velocity and occurred after the cattle had been on feed for approximately 70 d. The least-squares means for exit velocities and serum cortisol concentrations at this time and immediately before slaughter associated with these groups are presented in Table 29. The serum cortisol concentrations did not differ between these temperament categories at the mid-point sampling. However, the circulating concentrations of cortisol were higher ($P < 0.05$) in the animals classified as Excitable compared to their counterparts that had been identified as Intermediate or Calm immediately before they were transported to the processing facility for slaughter.

Muscle pH decline in the groups sorted at this time was consistent with the other sorting times (data not shown). The highest values were observed in the Intermediate group and lowest in the Excitable group at 0.5 h postmortem though this difference is smaller than the one observed when the animals were sorted on arrival to the feeding facility. Muscle pH did not differ with regard to temperament category at any other time measured. As noted earlier, temperature decline was not affected by temperament category (data not shown).

Table 29
Least-squares means for temperament traits of calf-fed steers stratified by temperament categories after approximately 70 d on feed

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
N	11	32	5		
Mid-point exit velocity	1.58c	2.56b	3.68a	0.09	<0.001
Mid-point cortisol, ng/mL	15.76	15.30	17.80	40.33	0.72
Final cortisol, ng/mL	16.05b	15.35b	24.42a	38.38	0.01

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

Table 30
Least-squares means for carcass traits of calf-fed steers stratified by temperament categories after approximately 70 d on feed

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Hot carcass weight, kg	350	349	343	1635	0.95
Adjusted fat thickness, cm	1.83	1.73	1.77	0.12	0.74
Longissimus muscle area, cm^2	80.91	82.79	85.87	86.57	0.61
Estimated kidney, pelvic, and heart fat, %	2.32	2.13	2.3	0.15	0.30
USDA yield grade	3.68	3.44	3.31	0.35	0.41
Lean maturity	161	159	156	123	0.71
Skeletal maturity	164	165	160	90	0.59
Overall maturity[a]	163	162	160	37	0.62
Marbling score[b]	443	421	458	8124	0.6
USDA quality grade[c]	703	694	711	1924	0.67

[a]100 = A^{00}; 200 = B^{00}.
[b]300 = $Slight^{00}$; 400 = $Small^{00}$; 500 = $Modest^{00}$.
[c]600 = $Select^{00}$; 700 = $Choice^{00}$.

Table 31
Least-squares means for meat quality traits of calf-fed steers stratified by temperament categories after approximately 70 d on feed

	Temperament category				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
Chemical fat, %	4.24	4.12	4.34	1.78	0.92
Moisture, %	73.09	73.30	73.64	1.75	0.74
*L**	48.00	48.43	48.90	5.82	0.77
*a**	30.23	30.87	30.03	1.66	0.21
*b**	21.87	22.64	21.79	2.23	0.23
Sarcomere length, µm	1.77	1.78	1.80	0.01	0.74
72-h Calpastatin activity	1.40a	0.94b	1.23ab	0.29	0.05
Warner-Bratzler shear force, kg	3.24	2.87	3.02	0.31	0.12

Least-squares means within a row with different letters (a-c) differ (*P* < 0.05).

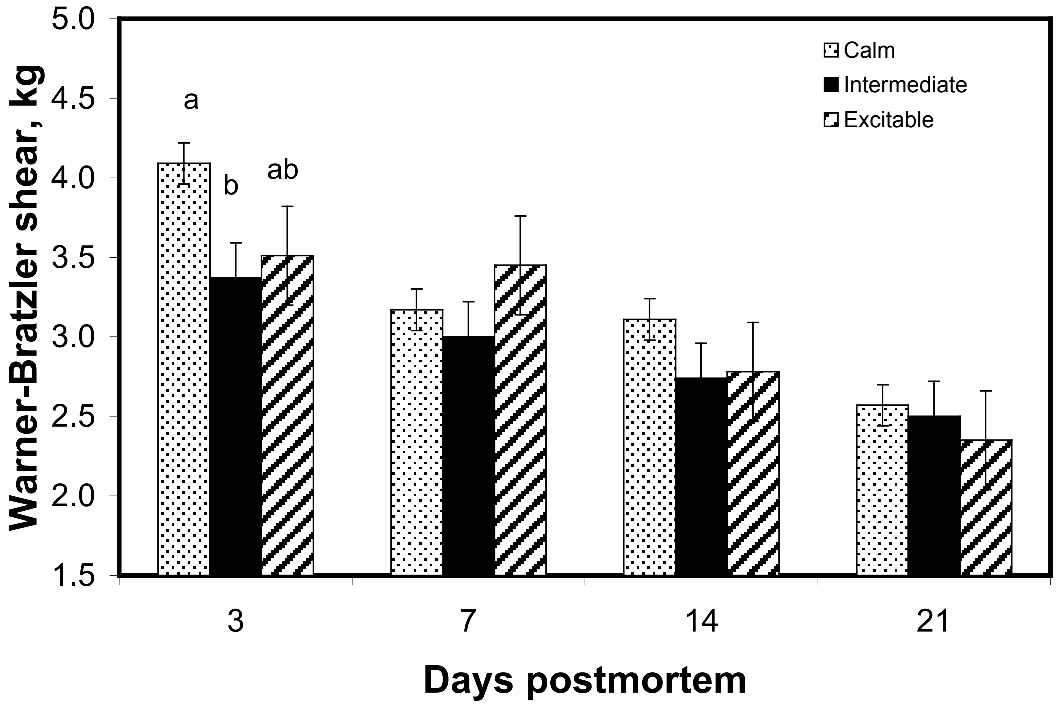

Figure 15. Least-squares means for the simple effects of temperament category within aging time on Warner-Bratzler shear force values of *M. longissimus lumborum* steaks from calf-fed feedlot steers segmented into temperament categories after approximately 70 d on feed.

USDA yield and quality grade factors are presented in Table 30. Carcass grade characteristics were not affected by temperament category. In fact, these characteristics were remarkably similar across the categories assigned at the mid point sampling.

Meat quality attributes for these steers stratified by the temperament classifications resulting from the mid-point evaluation are presented in Table 31. Calpastatin measured at 72-h postmortem was highest (P = 0.05) in muscles from cattle classified as Calm at the mid-point evaluation compared to the cattle classified as Intermediate. Animals identified as Excitable were intermediate with respect to 72-h calpastatin activity. Warner-Bratzler shear forced also tended (P = 0.12) to be affected by the mid-point temperament categories. The steaks from carcasses produced by cattle classified as Calm at the mid-point evaluation had the highest Warner-Bratzler shear force values, while steaks from the intermediate group had the lowest. Steaks produced by the cattle in the Excitable group had Warner-Bratzler shear force values that were intermediate to the other two groups.

The simple effects of temperament on Warner-Bratzler shear force values at each aging time measured are reported in Figure 15. After 3 d postmortem storage, the animals classified as Calm produced steaks that were less tender than those identified as Intermediate. The animals classified as Excitable at this time produced steaks with Warner-Bratzler shear force values that were intermediate to those of the other two groupings. This coincided with the differences in 72-h calpastatin activity values, suggesting that proteolysis may have been less extensive in the muscles of the Calm steers. By 7 d postmortem, this effect had diminished. In fact, the steaks obtained from the carcasses of the Excitable steers were numerically less tender than those of the other two groups though these values were not statistically different.

5.3. Discussion of sorting cattle with individual evaluations

Measures of animal temperament appeared to rank animals consistently, and differences in behavior observed between temperament categories before shipment to the feedlot remained throughout the feeding period. However, the magnitude of the differences between temperament categories appeared to diminish somewhat in later evaluations compared to those taken earlier in the production chain. This is consistent with the reports of Curley (2004) and Falkenberg et al. (2005). It is interesting to note that Curley (2004) found significant reductions in the exit velocities of Brahman bulls rated as excitable in subsequent evaluations taken 60 d apart. However, that investigator found no such reduction in calm or intermediate animals. The slower exit velocities at later evaluations might be attributable to the larger animals having greater difficulty in moving through the working facilities. Another explanation is that the animals displayed a learning behavior with increasing experience in being handled. Becker and Lobato (1997) reported that calves exposed to gentle handling over a period of time were more easily handled during subsequent workings than those that had not been handled by humans. In their study, previously handled calves displayed less aggressive behavior, attempted fewer escapes, and were more inquisitive during handling than those being handled for the first time. Because these measures of temperament are intended to identify animals that will be adversely affected by their responses to novel stimuli and therefore produce beef with less quality, the apparent learning behavior suggests that these measurements taken at later evaluations may have less predictive value than those taken earlier in the production system. Curley et al. (2004) and Falkenberg et al. (2005) both found stronger relationships between temperament ratings and tenderness and stress responsiveness when those ratings were made earlier in the animal's life.

Temperament affected tenderness in the yearling-fed cattle, but not in the calf-fed cattle. This confirms the conclusions reached in the previous analyses that yearling-fed and calf-fed animals were affected by temperament differently with regard to meat quality attributes. The root cause of this differing response is not readily apparent. It is notable that circulating cortisol concentrations differed between the temperament categories regardless of the time of sorting in the yearling-fed steer trial. In contrast very few of the comparisons made revealed differing cortisol concentrations between temperament categories in animals in the calf-fed trial. This may suggest that these animals did not differ in their stress responsiveness enough to have significant consequences on meat tenderness. However it is important to note that numerically, the cortisol concentrations observed in the calf-fed steers ranked the temperament categories in the manner expected. Perhaps the smaller sample size in the calf-fed trial contributed to the lack of differences.

Another possible contributor to the differing effects of temperament between these trials is time on feed, as this is the primary difference between these two trials once the animals reached the feedlot. The yearling fed steers were fed for 113 or 132 d, while the calf-fed steers were fed for 202 d. Previous reports indicate that increased time on feed increases tenderness of beef (Aberle et al., 1981; Tatum, 1981). These studies suggest that increasing days on feed will increase the tenderness of beef. Based on these data, it is not clear what mechanism mediates these tenderness differences, but it appears that time on feed may play a role. Perhaps part of the beneficial effects of time on feed is the removal of the negative effects of temperament.

It is troubling that sorting the yearling-fed cattle at differing points in the feeding program resulted in contradictory results. When those animals were sorted before shipment to the feeding facility, animals identified as having excitable temperaments produced beef that was less tender than the other animals in the trial. In contrast, sorting at the animals in that trial at later evaluation times show the opposite results. Clearly this is because the groups were distributed somewhat differently at each of these sampling times. In the analyses discussed earlier in this document, when temperament categories were assigned based on data compiled across all of the temperament evaluations, the animals identified as Excitable produced steaks with higher Warner-Bratzler shear force values than those identified as Calm or Intermediate. Experience with temperament data suggests that the negative effects of temperament occur in the extremely excitable animals and the ranking of animals that are not in this extreme group differs substantially between subsequent evaluations. Perhaps the groups identified as Calm and Excitable included too many of these animals that truly should have been defined as having Intermediate temperaments. This, coupled with even a modest learning behavior, may have affected the classification of these animals in the later evaluations to produce the observed discrepancies.

The ultimate goal of measuring temperament in feedlot cattle would be to provide feed yard operators a method to sort animals that will not fit industry meat quality targets and manage them differently than those that are more apt to meet those targets. Ideally, this would mean the identification of threshold values of exit velocity alone or in conjunction with other variables (i.e. pen scores, incoming body weight, body condition score, etc.) to be used to instantaneously sort cattle as they enter the feedlot or at re-implanting. Though a number of studies provide evidence that this may be possible, to date, insufficient data exist to identify these thresholds. These studies evaluated temperament in relation to meat quality rate animals within their contemporary group. Further research is necessary to determine if absolute values could be reliably compared across contemporary groups. If this is possible, still more research is needed to determine if threshold values exist that could be used in this capacity.

CHAPTER VI

CONCLUSIONS

Temperament traits were effective in sorting animals in this study. Differences identified in these traits before shipment to the feedlot remained evident in evaluations made after 70 d on feed. Additionally, animals identified as Excitable in this study were generally associated with higher circulating levels of glucocorticoids. This suggests that the exit velocity, pen score, and chute score data collected in this trial were related to the stress responsiveness of these animals. Furthermore, the relationships between the temperament indicators were consistent between contemporary groups and evaluations even though the magnitude of the values differed between contemporary groups and appeared to change over time.

The magnitude of the differences in exit velocity between the temperament categories appeared to decrease somewhat in evaluations made later in the feeding period. This may indicate that these animals habituated somewhat to handling. If this was the case, the later exit velocity measures might have less predictive power than those taken earlier in the feeding period. This might be the explanation for the differing results in sorting cattle into temperament categories at the various times during the feeding period with regard to muscle tenderness.

Temperament categories did not differ with regard to shipping shrink, average daily gain or dressing percentage. However, body weight was consistently lower in the Excitable animals at all times measured. This may suggest that the animals' gains were affected early in life but those effects had diminished by the time the study commenced. No carcass quality or yield traits were affected by temperament category.

Cattle with Excitable temperaments tended to be associated with less tender beef. The mechanism mediating this effect is not clear. None of the meat quality factors measured in this study differed between temperament categories. The greatest differences between temperament categories with regard to muscle tenderness were observed after short aging times in the Angus-sired yearling-fed cattle. However, the highest correlations calculated from data including all three contemporary groups between temperament traits and Warner-Bratzler shear force values were observed after the longest aging times.

It might be possible that the altered metabolism associated with the greater stress responsiveness in the Excitable cattle created conditions that were less favorable to calpain-mediated proteolysis. This reduction in proteolysis may have been enough to create the tenderness differences observed between temperament categories. However, because other factors were the predominate drivers of tenderness after shorter aging times, the correlation was not evident until later when proteolysis became more important in determining the overall tenderness.

The contemporary groups used in this study exhibited differing responses to the effects of temperament category. This is surprising because the relationships between temperament traits were consistent across the contemporary groups. This may partially be due to variation in the magnitude of the differences in temperament between the categories within each contemporary group.

Sorting cattle based on individual evaluations of temperament produced drastically differing results at different evaluation times during the feeding period. When the yearling-fed cattle were sorted before shipment to the feeding facility, the cattle identified as Excitable produced steaks that were less tender than those with calmer temperaments. When these cattle were sorted at later evaluations, the opposite effect was observed. Sorting cattle based on temperament at any stages of production did not predict differences in muscle tenderness in the calf-fed steers.

The negative effects of temperament on production traits, and presumably meat quality traits are associated with the extreme cases. Animals that are moderate in temperament will vary with their ranking within the contemporary group, but those that are truly Excitable will consistently be ranked on the ends. The temperament categories in the yearling-fed cattle may have included some animals that would have been more suitably classified as Intermediate. The differing results of sorting the yearling-fed cattle are most likely due to the redistribution of these animals between the Intermediate and Excitable groups.

From these data, it is apparent that measures of temperament are consistent and can be used to sort cattle into groups that differ in behavior and stress responsiveness. Temperament appears to affect meat tenderness; however, the mechanism mediating that effect is not clear, and this relationship between temperament and tenderness appears to be affected multiple factors. Further investigation is warranted to provide greater insight into the feasibility of using these traits for sorting cattle under commercial conditions. Future studies in this area should examine large numbers of cattle from diverse origins to elucidate the factors affecting the relationship between temperament and tenderness. Furthermore, smaller, highly-controlled studies using cattle that differ widely in temperament are needed to elucidate the mechanisms resulting in these effects.

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